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Dear Mr. Recht :

Re: **Settlement Agreement**
Section B. Fire Safety Research

Enclosed is the Final Report prepared by J. Michael Bennett entitled "Survey of Fire Intervention Technologies For Their Potential Application In Motor Vehicles."

This report relates to Task 1 of Project B.4 (Evaluation of Potential Fire Intervention Materials and Technologies).

Sincerely,

DA Collins

David A. Collins
Attorney

Enclosure

SURVEY OF

FIRE INTERVENTION TECHNOLOGIES

FOR THEIR POTENTIAL APPLICATION IN

MOTOR VEHICLES

May 15, 1998

Prepared by

J. MICHAEL BENNETT

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I. INTRODUCTION

A. Background

1. Program and Project

The General Motors Corporation, in cooperation with the National Highway Traffic Safety Administration, is conducting a five year motor vehicle fire safety research program. The program involves research to : (1) understand possible mechanisms involved in post-crash passenger vehicle fire initiation and propagation, (2) develop information on the flammability properties of materials and fluids used in passenger vehicles, and (3) evaluate fire intervention materials and technologies which could potentially intervene in the initiation or propagation of passenger vehicle fires. The overall objective of the research program is to develop information which will potentially enhance passenger motor vehicle fire safety.

The work described by this report is part of a project entitled “Fire Intervention Materials and Technologies”. The objectives are:

1. to evaluate the appropriateness of existing fire intervention materials and technologies for possible automotive applications, and

2. to recommend technologies for further investigation and experimentation.

Since these technologies are currently directed toward other applications, they may require some modification or further development for automotive use.

This report describes:

* the results of a literature search performed to identify the many different types of fire mitigation technologies that might have some relevance to motor vehicles,

* the nature and results of survey forms sent to several hundred manufacturers of fire mitigation technologies, and

* a rating process, based on expert judgment, devised to evaluate the relative merits of the different technologies for possible motor vehicle applications.

These results, combined with other factors, may be used to decide which technology types will be further evaluated.

2. Automotive Fire Scenarios

Table 1 illustrates possible combinations of combustible materials and ignition sources that could result in an post-crash motor vehicle fire. The combustible materials are grouped into

TABLE 1 - MATRIX OF POSSIBLE IGNITION SOURCE/COMBUSTIBLE MATERIAL COMBINATIONS THAT COULD INITIATE AUTOMOBILE FIRES

F-FRONT AREA R-REAR AREA (INCLUDING UNDERNEATH)	IGNITION SOURCES														
	ELECTRICAL SPARKS/ SHORTING								HOT SURFACES					FRICTION/ SPARKS	
COMBUSTIBLE MATERIALS	LOCATION	BATTERY/PRIMARY CABLES	OTHER ELECTRICAL CABLES	HEADLIGHTS ASSEMBLY	TAILLIGHT ASSEMBLY	COIL/DISTRIBUTOR SPARK PLUGS	ALTERNATOR FAN	FUEL PUMP	EXHAUST MANIFOLD	CATALYTIC CONVERTER	EXHAUST PIPE	MUFFLER	BRAKE LININGS	FRONT IMPACT	REAR IMPACT
LOCATION		F	F	F	R	F	F	R	F	F/R	F/R	R	F/R	F	R
SOLIDS															
WIRING INSULATION	F/R	X	X	X	X	X	X	X	X	X	X	X	X		
PLASTIC DUCTING	F	X	X	X		X	X		X	X	X				
PLASTIC FLUID RESERVOIRS	F	X	X	X		X	X		X						
HEAT/SOUND INSULATION	F/R	X	X	X	X	X	X		X						
TIRES	F/R														
TRUNK LINING	R				X										
SURFACE COATINGS	F/R		X					X	X	X	X	X			
GASOLINE															
FUEL LINES/FUEL RAIL	F/R	X	X	X		X	X	X	X	X	X	X	X	X	X
VAPOR CANISTER	F	X		X		X	X		X	X	X			X	
FUEL TANK	R				X			X		X	X	X	X		X
OTHER FLUIDS															
BRAKE FLUID	F/R	X	X	X		X	X	X	X	X	X	X	X	X	X
TRANSMISSION FLUID	F/R	X	X	X		X	X		X	X	X		X	X	
POWER STEERING FLUID	F	X	X	X		X	X		X	X	X			X	
OIL	F	X	X	X		X	X		X	X	X			X	

three categories: solids; gasoline (or other operating fuel); and other flammable fluids. The ignition sources are grouped into three categories: electrical sparks/shorting; hot surfaces; and friction/sparks due to grinding and deformation during a collision. The location of each of these materials and sources is noted as either in the front (F), which is defined as extending from the front bumper to the engine compartment bulkhead, the rear (R), which extends from the bulkhead, under the car and to the rear bumper, and the combination of both (F/R). An "X" is marked in the box at the intersection of a material and ignition source if they might overlap temporally and spatially. The identification of these possible fire scenarios does not suggest that ignition and fire will always occur, but only that the possibility exists under such post-crash conditions.

B. Method of Data Collection

1. Survey Development

In the spring of 1996 a process began to identify companies who offer technologies that might improve the fire safety of passenger vehicles. These technologies might be used either off-the-shelf or with modifications. This process included database searches of fire safety organizations, trade organizations, Internet listings, and the personal libraries of the project team members. Included in this collection of organizations were foreign companies with special products. At the conclusion, a total of 300 manufacturers were identified as candidates for supplying relevant products. Products used in other industries, such as fire barriers used in construction, were also considered as possible product concepts for automotive use.

Drafts of eleven survey types were prepared to address the unique data requirements associated with the different types of technologies. Advice was solicited from several of the manufacturers as to the reasonableness, relevance and feasibility of collecting data using the surveys as initially proposed, and suggestions were solicited on additional or alternative information that would assist in accomplishing the goal. The set of requested data was then reduced to the minimum necessary to assess the potential impact of a technology's use in automobile applications. It was understood that many of the manufacturers may not have portions of the detailed data that were requested, and in fact, significant portions of many survey forms were not completed. Evaluation of the data was then performed based upon the information received, follow-up telephone calls when necessary, and engineering judgment.

A listing of the surveys and the contents of the overall packages, as mailed, are contained in Appendix A. A definition of each broad survey category and range of applicable product types and a discussion of the rationale of the content for each survey type is included in Appendix B.

2. Survey Recipients, Response

Three hundred survey packages were mailed on the first of September, 1996. The surveys were returned through the end of February, 1997. A total of 38 companies returned surveys on 66 products. Eight companies sent product literature but no surveys. After a review of their literature, however, it was determined that their products were similar to those described in the other surveys.

Of the 66 products identified in the surveys, 40 were considered active systems (including 11 detector products), 12 were passive systems, and 11 were fire resistant materials. Three active system products, including two extinguishing chemicals (apart from a fire extinguishing system) and a handheld fire detection device used by firefighters, were not rated. The two extinguishing chemicals were not rated due to their lack of association with a legitimate system that could provide a discrete, stand-alone solution to motor vehicle fires, a criterion expressed in the survey instructions. The handheld detector device was not rated due to: 1) the small likelihood of mounting such a device on a vehicle and 2) the requirement for occupants to be capable of operating the device and exiting the vehicle to utilize it, which would restrict it to scenarios which are outside those under consideration in this program. Three of the fire resistant fabrics received no points when rated, since they could not address the fire scenarios deemed critical for investigation.

Product surveys were submitted for ten of the eleven general product types that were identified. Other companies that manufacture pertinent products, some of which are unique and promising in nature, chose not to return surveys. The rationale for such a response varied, but most expressed a limitation of personnel resources available to dedicate to the task of compiling the data. This position was usually accompanied with a general skepticism about the promise of such products finding a new market in the automotive market. Other companies determined that their products were not ideally suited for such an application, even with substantial modifications. During the review of the submitted surveys and associated literature, it became obvious that some submitters purported a range of applicability and performance level that could not be documented solely by the data submitted. This may be due to their lack of understanding of the automotive environment or an over-zealousness to develop a potential market for their products. Other products, such as the self-sealing materials and aerosol generators, revealed unexpected opportunities for automotive applications.

No products were submitted for the “non- or less flammable fluids” category. Such products could be used to replace oils, transmission, brake and power steering fluids. These products are currently used in other industries where flammability considerations are critical, such as in mining equipment. Survey packages were sent to companies that make such products, but upon contact with them it was found that they chose not to supply product data.

Only one manufacturer of powder panels currently exists, and this manufacturer has decided to limit their production of such devices for application on certain military aircraft, which is their primary business area. As a result they did not submit a completed survey package, but provided verbal data of their product specifications. Variations of this product are being evaluated for potential automotive use, so it was considered using current available data.

Active fire protection products included conventional fire extinguishers using clean agents, dry chemicals, water mist and aqueous film-forming foam (AFFF), gas generators using pure inert gas and hybrids that dispense clean agents and dry chemicals, pyrotechnic aerosol systems, tubular fire extinguishing systems and explosion suppression systems. Passive technologies included self-sealing fluid lines/components, fluid shut-off devices, flame arrestors, reticulated foams, crash resistant fuel tanks, engine shutoff devices and powder panels. The fire resistant materials included fabrics, plastics, and intumescentiablative coatings.

A listing of the companies that responded with completed product surveys, along with their addresses, is included in Appendix F of this report.

II. DESCRIPTION OF TECHNOLOGIES

This section provides generic descriptions of the three classes of fire mitigation technologies under consideration for this project, focusing on their features, mitigation approaches, performance, weight and size. Tables 2 and 3 are summaries of such information, specified by each technology type in each class, organized identically with this section. The information in Tables 2 and 3 is compiled from the information received in the surveys returned by manufacturers.

A. Active Systems

1. General Description

Active systems typically consist of a fire sensor or some other means of sensing a fire, an electromechanical or manual device to initiate the suppression process, and an extinguishant material. Table 2 summarizes the attributes of the systems described below.

A variety of fire detection devices and active system initiation methods are available. Thermal spot detectors, functioning as simple thermocouples or thermopiles, can generate electrical signals at pre-set temperature thresholds and initiate an electrical solenoid valve mechanism. Linear detectors, which are wires or tubes that are routed and mounted through the protected region of interest, are activated by heat from a fire. These devices are typically triggered by the closing of contacts between dissimilar metals or bimetallic strips, or by a pressure buildup within a hermetically sealed tube (e.g., pneumatic fire detection devices). This in turn transmits a signal to an appropriate transducer at one end of the device and subsequently to the extinguisher valve. The inherent response time of these devices is on the order of ten seconds. The actual activation time depends on the fire scenario and the location of the detector relative to the fire. Other detectors function by detecting electromagnetic radiation from a fire of various spectra, typically infrared or ultraviolet, but sometimes in the visible wavelengths. In these units certain emission wavelengths that are generally unique to common hydrocarbon fires are selectively detected, while simultaneously filtering the remaining wavelengths. In some of the more elaborate optical detectors, multiple wavelengths in the infrared and/or ultraviolet must be present to confirm the presence of a fire and subsequently trigger the extinguisher. More sophisticated forms of optical detection exist, such as machine vision, which processes light signals to recognize shapes and patterns of motion that are unique to particular fires. These devices can be coupled with fiber-optic signal transmission cables, although they exist in prototype form only at this time. The detectors described above can be used with virtually all of the active extinguishing systems discussed next.

Active fire extinguishing systems use many different types of extinguishants, including dry chemicals, wet chemicals, inert gases and other clean agents. Dry chemical powders commonly in use include mono-ammonium phosphate, sodium bicarbonate and

TABLE 2 – DESCRIPTION OF TECHNOLOGY (ACTIVE SYSTEMS)

TECHNOLOGY TYPES	APPLICATION AREAS	COMBUSTIBLE IGNITION SOURCES ADDRESSED (see legend below)	ANTICIPATED COST ($)		WEIGHT ESTIMATE (LB)	
			CURRENT	MASS QUANTITIES	FRONT	REAR
ACTIVE SYSTEMS						
FIRE DETECTORS						
OPTICAL	FRONT, REAR	A-N/1-14	1251990	125-890	0.5-6.5	0.5-6.5
LINEAR HEAT	FRONT, REAR	A-N/1-14	50	35	0.5-10	0.5-10
LINEAR PNEUMATIC	FRONT, REAR	A-N/1-14	660	483	0.5	0.5
HEAT	FRONT, REAR	A-N/1-14	800	600	0.1	0.1
GAS	FRONT, REAR	H-N	600	400	N/A	N/A
MACHINE VISION	FRONT, REAR	A-N/1-14	20 K	350	2	2
CONV. FIRE EXT.						
CLEAN AGENT	FRONT, REAR	A-D, F-N/1-14	500-995	125-995	10.8	23.4
DRY CHEMICAL	FRONT, REAR	A-N/1-14	58-2140	17-1070	6.48	14.04
WATER MIST	FRONT, REAR	A-D, F-N/1-14	N/A	N/A	8.64	18.72
AFFF	FRONT, REAR	A-N/- 14	N/A	N/A	6.48	14.04
GAS GENERATORS						
INERT GAS	FRONT, REAR	A-D, F-N/1-14	N/A	60	9.72	21.06
WATER HYBRID	FRONT, REAR	A-D, F-N/1 - 14	N/A	100	6.48	14.04
POWDER HYBRID	FRONT, REAR	A-N/1-14	N/A	70	4.68	10.53
AEROSOL	FRONT, REAR	A-N/1-14	250	70	2.7	5.85
EXPLOSION SUPP. SYS.						
DRY CHEMICAL	FRONT, REAR	A-N/1-14	2200	1200	6.48	14.04
CLEAN AGENTS	FRONT, REAR	A-D, F-N/1-14	2200	1200	10.8	23.4
TUBULAR EXTINGUISHER	FRONT, REAR	A-Nil-14	N/A	N/A	6.48	14.04

COMBUSTIBLE MATERIALS (A-N)					IGNITION SOURCES (l-14)				
A-Wiring Insulation	B-Plastic Ducting	C-Plastic Fluid Reservoirs	D-Heat/Sound Insulation	E-Tires	1-Battery/Primary Cables	2-Other Electrical Cables/Bundles	3-Headlight Assembly	4-Tail Light Assembly	5-Coil/Distributor Spark Plugs
F-Trunk Lining	G-Surface Coatings	H-Fuel Lines Fuel Rail	I-Vapor Canister	J-Fuel Tank	6-Alternator Fan	7-Fuel Pump	8-Exhaust Manifold	9-Catalytic Converter	10- Exhaust Pipe
K-Brake Fluid	L-Transmission Fluid	M-Power Steering Fluid	N-Oil		11-Muffler	12-Brake Linings	13-Front Impact Sparks	14-Rear Impact Sparks	

LEGEND: Combustible /Ignition Sources Addressed (Column 3)

TABLE 2 - DESCRIPTION OF TECHNOLOGY TYPES (ACTIVE SYSTEMS) - CONT.

TECHNOLOGY TYPES	EXPECTED ADVANTAGES					EXPECTED DISADVANTAGES				AVAILABILITY			CURRENT USES	OTHER COMMENTS
	WEIGHT	RELIABILITY	CRASHWORTHY	RE-IGNITION ADDRESSE	OTHER	TOXICITY	COST	WEIGHT	SAFETY	MASS-PRODUCED	PROTOTYPE	THEORIZED		
ACTIVE SYSTEMS														
FIRE DETECTORS														
OPTICAL	X		X				X			X			marine, RV, commercial/military vehicles	
LINEAR HEAT	X				COST					X			buses, off-road, on-road	
LINEAR PNEUMATIC	X						X			X			aircraft, military vehicles	
HEAT	X						X			X			vehicles	
GAS							X	X		X			buses, alt. fueled vehicles	
MACHINE VISION	X						X				x		NONE YET	
CONV. FIRE EXT.														
CLEAN AGENT							X	X		X			marine, buses, RV, armored vehicle	
DRY CHEMICAL				X	COST					X			buses, boats, off-road	corrosion
WATER MIST				X				X		X			generators, turbines, vehicle prototypes	corrosion
AFFF				X						X			train engines	
GAS GENERATORS														
INERT GAS			X		COST			X	X	X			military aircraft	
WATER HYBRID				X	COST				X		X		NONE YET	corrosion
POWDER HYBRID	X			X	COST				X		X		NONE YET	corrosion
AEROSOL	X			X	COST				X		X		engine compartments, computer rooms	corrosion
EXPLOSION SUPP. SYS.														
DRY CHEMICAL				X	HI-SPEED		X			X			military vehicles, industry	
CLEAN AGENTS					HI-SPEED		X	X		X			military ground vehicles	
TUBULAR EXTINGUISHER			X	X	SPACE EFFICIENT						x		NONE YET	

TABLE 3: DESCRIPTION OF TECHNOLOGY TYPES (PASSIVE SYSTEMS, FIRE RESISTANT MATERIALS)

TECHNOLOGY TYPES	APPLICATION TYPES	COMBUSTIBLE/ IGNITION SOURCES ADDRESSED (see legend below)	ANTICIPATED COST ($)		WEIGHT ESTIMATE (LB)	
			CURRENT	MASS QUANTITIES	FRONT	REAR
PASSIVE SYSTEMS						
FLAMEARRESTOR	TANK, CANISTER, BULKHEADS	A-N/1-14	122	79.3	0.6	5.5
ENHAN. CRASH. FUEL TANKS	FUEL TANK	J/4,7,9-12,14	550-3000	100-3000	0	<5
FUELSHUTOFFDEVICE	FLUIDLINES	H.K/1-14,M, N, L/ 1-3,5-6,8-10,13	20	10.0-35.0	0.01-5each	N/A
RETICULATED FOAM	FUEL TANK	J/4,7,9-12,14	19.6	13.44	0	2.7-2.8
SELF-COMPONENTSSEALING	FLUIDSYSTEMS	H-N/1-14	N/A	N/A	0?	0?
POWDERPANEL	FUEL TANK	J/4,7,9-12,14	16?	16?	0	7.72
ENGINESHUT-OFF	ENGINE	A-D,G-N/l-7	N/A	N/A	1	0
FIRE RES.						
FIRE RES. PLASTICS	FRONT, REAR BULKHEADS, OTHERITEMS	A-N/1-14	2.7-420	2.7-420	0.17-9.17	0.85-45.83
FIRE RES. FABRICS	FRONT, REAR BULKHEADS	A-N/1-14	<1200	<1200	3.13-5.12	15.65-26
INTUM/ABLATIVE COATINGS	FRONT, REAR BULKHEADS	A/N1-14	224-720	172-675	6-7.5	30-37.5

COMBUSTIBLE MATERIALS (A-N)					IGNITION SOURCES (1-14)				
A-Wiring Insulation	B-Plastic Ducting	C-Plastic Fluid Reservoirs	D-Heat/Sound Insulation	E-Tires	1-Battery/ Primary Cables	2-Other Electrical Cables/Bundles	3-Headlight Assembly	4-Tail Light Assembly	5-Coil/Distributor Spark Plugs
F-Trunk Lining	G-Surface Coatings	H-Fuel Lines Fuel Rail	I-vapor Canister	J-Fuel Tank	6-Alternator Fan	7-Fuel Pump	8-Exhaust Manifold	9-Catalytic Converter	10- Exhaust Pipe
K-Brake Fluid	L-Transmission Fluid	M-Power Steering Fluid	N-Oil		11-Muffler	12-Brake Linings	13-Front Impact Sparks	14-Rear Impact Sparks	

LEGEND: Combustible /Ignition Sources Addressed (Column 3)

TABLE 3 - DESCRIPTION OF TECHNOLOGY TYPES (PASSIVE SYSTEMS, FIRE RESISTANT MATERIALS) - CONT.

TECHNOLOGY TYPES	EXPECTED ADVANTAGES					EXPECTED DISADVANTAGES				AVAILABILITY			CURRENT USES	OTHER COMMENTS
	WEIGHT	RELIABILITY	CRASHWORTHY	RE-IGNITION ADDRESSED	OTHER	TOXICITY	COST	WEIGHT	SAFETY	MASS-PRODUCED	PROTOTYPE	THEORIZED		
PASSIVE SYSTEMS														
FLAME ARRESTOR	X	X		X	cost, minimal apace					X			auto fuel tanks, firewalls	use on firewalls
ENHAN. CRASH. FUEL TANKS	X	X	X							X			aircraft, police cars, race cars	
FUEL SHUTOFF DEVICE	X		X		cost, small					X			sprinkler heads, fluid valves, aircraft	
RETICULATED FOAM	X	X	X		cost, no space needed					X			military, racing, law enforcement, aircraft	static decomposition
SELF-SEALING COMPONENTS	X				minimal space					X			military, aviation, law enforcement	extent of damage
POWDER PANEL	X		X	X	minimal space, cost						X		aircraft	damage in use
ENGINE SHUT-OFF	X									X			marine	
FIRE RES. MATERIALS														
FIRE RES. PLASTICS	X			X	cost (some)			X		X			buildings, auto trim, fuel lines, cable jackets	
FIRE RES. FABRICS	X	X	X	X			X			X			driver suits, auto heat shields, hood liners	
INTUM/ABLATIVE COATINGS		X	X	X	flexible		X	X		X			petrochemical, aerospace, school buses	

potassium bicarbonate. Wet chemical extinguishants are those that feature a water base which "wets" surfaces to cool them and blocks the interaction between fuels and oxygen. Pure water can be used, and in systems that protect enclosed spaces water mist has recently been shown to be a weight efficient means of extinguishing fires. Some additives to water, such as Aqueous Film-Forming Foam (AFFF), can be used to create a film which prevents fuel vaporization and thereby combustion. Inert gases such as carbon dioxide and nitrogen can be effectively used to extinguish many types of fires. Inert gases primarily act by displacing oxygen, thus suffocating the fire. Clean agents are chemicals that behave in a similar manner to inert gases, leaving no corrosive solid or liquid residue, but typically are effective at lower concentrations than inert gases. Clean agents have varying degrees of chemical inhibition of the combustion process, in addition to oxygen starvation and cooling capabilities. They can be classified into two categories: streaming agents, which are dispersed toward the fire initially as a liquid stream and eventually vaporize, and total flooding agents, which rapidly gasify after discharge to fill complex enclosures and flow around comers or geometric obstacles. The most popular of the clean agents were the halogenated fluorocarbons, or Halons, which were used most frequently for the majority of this century. Dry and wet chemicals exhibit some capability in preventing the re-ignition of fires that are initially extinguished, whereas the inert gases and clean agents do not.

Conventional fire extinguishing systems that may potentially be suitable for vehicle use are often derivatives of portable handheld extinguishers, and consist of a pressurized container, discharge valve, and some means to initiate the valve. The design, construction and performance of the pressurized cylinders are certified by organizations such as Underwriter's Laboratories.

Many different means of initiation can be used with these systems. For portable extinguishers, the simplest valves are operated by squeeze handles that are used by the operator. Derivatives can be designed for remote manual activation in which the squeeze handle is activated by a cable release. These remote devices may be used with other valve mechanisms, such as rupture disks and spring-loaded firing pins. An alternative is a plunger type mechanism that is impacted once by the operator. These systems can also be activated automatically once a hazardous condition is detected, in case an operator is not present or is not able to personally activate the device. The simplest and lowest cost of these alternatives is a frangible bulb, such as is used in sprinkler systems. These bulbs are designed to fracture at a pre-set temperature (which correlates to a hazardous condition such as a fire), releasing the contents of the extinguisher that were restrained originally by the bulb.

Solid propellant gas generators are derivatives of automotive air-bag inflators. These devices were recently developed and demonstrated to extinguish fires by generating inert gases and particulates which are combustion products of solid-phase propellants. A variation is known as a hybrid system, where the hot inert exhaust gases from the generator are used to vaporize and expel another extinguishing material housed in an adjoining chamber in the same unit.

Aerosol generators are relatively new devices that are closely related to gas generators in form and function. These normally non-pressurized devices consist of pyrotechnic solid materials that are similar to the gas generator propellants. When initiated they react exothermically to create large quantities of aerosol fire extinguishing particles (less than one micron in diameter).

Explosion suppression systems are closely related to conventional fire extinguishing systems, with features that enhance their response time. These devices respond within milliseconds. These systems are initiated automatically from the signal of a pressure switch or a fast response optical detector. An electrical signal is produced that triggers an ultra-fast solenoid valve or pyrotechnic squib that fires and fractures a rupture disk in the extinguisher. This action releases the stored pressurized extinguishant that was restrained by the rupture disk. Either clean agents or dry chemicals are used in such systems.

The final variety of active protection technologies, the flexible tubular wet pipe fire extinguishing system, is among the most recent and innovative. The storage and delivering component of this device consists of a flexible, thermoplastic tubing, typically an inch or less in diameter, that is sealed and pressurized with extinguishant. This tube can be routed in serpentine fashion throughout the region to be protected, and permanently mounted. When a fire breaks out in proximity to the device, it will rupture (due to thermal weakening) and eject its contents. No active detection device is required with this system, but could be used to enhance its performance.

2. Application Areas

Active systems offer the potential of protecting the engine compartment, the rear trunk/fuel tank area, the area under the car, and even in the passenger compartment. The fire detection device must be mounted in the compartment that is to be protected and the signal routed to the discharge valve of the extinguishing material reservoir. The extinguishant storage container can be remotely located, such as in the trunk or under the rear seat, to accommodate acceptable storage locations and to be more strategically placed to improve crashworthiness. A plumbing network can then transport the discharged extinguishant to one or more desired areas. Some variations, such as the tubular systems, explosion suppression systems or aerosol generators, must be mounted in the region where the fire is anticipated because they are only capable of supplying a local application of extinguishant.

3. Fire Scenarios Addressed

Active systems can be designed to address virtually all potential post-crash fire scenarios, from the burning of solids, gasoline or other flammable liquids. The combustible material and ignition source codes listed in Table 2 signify which combinations are addressed with each technology type. They are explained in the legend at the bottom of the table, and are consistent with those listed in Table 1.

4. cost

Table 2 also includes estimates of the anticipated costs of the various technologies for those products where such information was reported in the surveys. As revealed from the survey data, costs vary widely among the active systems and within each technology type. The listed range of costs is the extreme values of those reported for products in each technology type. The price quoted for large lot sizes was usually estimated, since lot sizes large enough for automotive use are not normally produced. These cost estimates do not include investment costs associated with manufacturing the vehicle, the costs of integrating the feature into overall vehicle designs, or the costs of validating the systems in motor vehicle applications. Among the extinguishing systems, the conventional dry chemical extinguishers and the pyrotechnically activated devices generally offered systems at the lowest cost (with low costs forecast for the gas generator units due to industry experience in automotive airbag initiator manufacture). The least expensive detectors were the linear heat detectors, followed by the linear pneumatic, optical, machine vision and gas detectors.

5. Weight

The weight estimate data requested in the surveys were not always supplied or were inconsistent amongst similar products. As a result, a standardized estimate of system weight was developed based upon the extinguishing material and hardware used, and the size of the application area. The criteria used to estimate system sizes are shown in Table 4.

The volumes of the regions to be protected on the vehicle were assumed to be 2 1.2 cubic feet in the front end and 45.9 cubic feet in the rear end. The rear estimate includes the region under the bottom of the vehicle from the rear bumper to the front bulkhead location. The expected performance of the extinguishants was expressed as an application density, which is the mass of extinguishant required to protect a given unit volume. The estimate mass of extinguishant needed is approximate for several reasons:

* Very little experimental data are available on the performance of these materials in an automotive fire environment.

* Each automobile varies in geometry, and every fire varies in configuration.

* The efficiency of the distribution of the extinguishant will affect the amount of extinguishant required.

* The front end is a heavily obstructed compartment, which will greatly reduce the efficiency of the extinguishant usage. The obstructions inhibit extinguishant distribution, diminishing its total flood capability.

* Large openings, particularly near the ground, result in a high degree of leakage that increases the design quantity of an extinguishant. A safety factor of three is added to the extinguishant mass estimate to account for this variability.

These mass estimates are multiplied by a factor of two to account for storage hardware when the material is stored under pressure, and by a factor of 1.5 to account for non-pressurized hardware. Since the storage hardware for the powder panels is limited to very thin plastic sheet or aluminum foil structure, the weight scale-up factor is only 1.1. It is assumed that the reduced weight of the plastic structure of the tubular extinguisher is offset by the increased surface area of the device. As a result, a weight scale-up factor of 2.0 is used, which is identical to the other

TABLE 4 - EXTINGUISHING SYSTEM WEIGHT ADJUSTMENT CRITERIA

Extinguishant Type	Application Density* (lbs. per cubic meter)	Rationale
Water Mist	2.4	Estimated performance: 20% better than clean agent
Clean Agent	3.0	Estimated performance: twice the normal design densitv of Halon
Drv Chemical	1.8	Estimated 40% better than clean agent
Aerosol	1.0	Conservative estimate of improvement over Halon
Inert Gas Generator	3.6	Similar to Clean Agents on mass basis, but hot gas requires 20% more extinguishant
Water-Based Foams	1.8 36.0	Foarn Expansion Ratio of 1000 (Assumed) Foam Expansion Ratio of 50 (Assumed)

* For initial knockdown; re-ignition suppression feature accounted for elsewhere

Estimated Volume of Front Section	21.2 cubic feet
Estimated Volume of Rear Section and Under Car	45.9 cubic feet
Assumed Application Thickness of Coatings, Fire Resistant Materials	0.1 in.

Increase For Hardware For Pressurized Systems - Clean Agent, Dry Chemical, Water Mist/AFFF, Etc.	2.0x
Increase For Hardware For Non-Pressurized Systems - Gas Generator, Aerosol	1.5x
Increase For Hardware For Powder Panels	1.1x
Increase For Hardware For Tubular Extinguishing Svstems	2.0x

Each mass rating is multiplied by factor of 3 to account for leakage, redirection away from fire or deposition on obstacles, etc.

pressurized hardware.

It should be noted that two extreme values for AFFF application density are noted based upon which AFFF specification is acceptable for the overall automobile environment. An AFFF blend with a volumetric expansion ratio of 1000 (ratio of foam volume to liquid volume) can be very efficient for such an application per unit storage volume, and result in the lower application densities. This variation is presumed in the weight estimates and product evaluations in this study. However, such blends may not be acceptable in their functionality at the low temperatures encountered in automotive applications. In such cases, blends with expansion ratios as low as 50 may be necessary, which have such low temperature capability. This reduced expansion ratio results in larger application densities and greater mass requirements.

The total estimated system weights for the front or rear applications for different technology types are shown in Table 5, using the criteria defined in Table 4. These estimates are consistent with the entries in Table 2. It is assumed that the weight of a system designed to protect both the front and rear will be the sum of the weights of the systems sized for the front and rear individually. Although a system could be designed to protect either zone by switching the extinguishing material flow to the region desired, the need to protect both regions simultaneously may be desirable.

The estimated system weights for almost all of the active systems are expected to be consistent with the weights shown in Table 5. The weights of the fire detectors disclosed in the surveys can vary considerably. Optical detectors range from 0.5 to 6.5 pounds. Linear detectors range from 0.5 to 10 pounds. The single linear pneumatic detector submitted was reported as weighing 0.5 pounds. Heat detectors were reported to weigh 0.1 pounds. The gas detector unit, including the central gas analyzer, was estimated to weigh 4 lbs. The machine vision detector was estimated to weigh 2 pounds in each region (front and rear), since the four-pound unit with ten fiber optic detector leads would be sufficient to cover both regions.

6. Advantages/Disadvantages

Selected notable advantages and disadvantages of the various technologies are shown in Table 2. If discharged accidentally, clean agent systems vaporize leaving no residue, unlike dry chemical powder extinguishants which can be potentially corrosive if left unattended for an extended period.* The AFFF extinguishants may be potentially corrosive as well. To prevent the freezing of the stored water in water mist extinguishers at low temperatures, some additives are usually used to lower the freezing point, but these can also be corrosive.

Inert gas generators used in automotive air bags are crashworthy. They can be heavy, due to the large amounts of hot inert gas necessary for extinguishment. In addition, extreme heat is generated on the outside of the generator and distribution plumbing when these units are initiated. This can pose a safety hazard to individuals and overheat surrounding materials if the unit is not mounted appropriately.

* Reference: Fire Protection Handbook (Quincy, MA: NFPA, 17th ed.) l-79,5-258

TABLE 5 - SYSTEM WEIGHT ESTIMATES FOR DIFFERENT EXTINGUISHANT/HARDWARE COMBINATIONS

Extinguishant/Hardware Type	Weight Estimate(with Hardware) - lbs.		
	Front	**Rear**	**Front/Rear Combination**
Clean Agents			
Conventional Extinguisher	10.8	23.4	34.2
Gas Generator/Hybrid	8.1	17.55	25.65
Tubular Extinguisher	10.8	23.4	34.2
Water Mist			
Conventional Extinguisher	8.64	18.72	27.36
Gas Generator/Hybrid	6.48	14.04	20.52
Dry Chemical			
Conventional Extinguisher	6.48	14.04	20.52
Gas Generator/Hybrid	4.86	10.53	15.39
Tubular Extinguisher	6.48	14.04	20.52
Powder Panel	3.56	7.72	11.28
Aerosol	2.7	5.85	8.55
Inert Gases			
Conventional Extinguisher	12.96	28.08	41.04
Gas Generator	9.72	21.06	30.78
Water-based Foams (AFFF, etc.)*			
Conventional Extinguisher	6.48/129.6	14.04/280.8	20.52/410.4
Gas Generator/Hybrid	4.86/ 97.2	10.53/210.6	15.39/307.8
Tubular Extinguisher	6.48/129.6	14.04/280.8	20.52/410.4

* 1000x/50x Expansion Ratio of Foam

Hybrid units that dispel water incur fewer weight penalties due to the more efficient extinguishing capability of water over inert gas, and may prevent re-ignition in some cases. The aerosol units are identical to the dry chemical hybrid units in terms of their advantages and disadvantages.

Both the dry chemical and clean agent explosion suppression systems feature the advantage of high-speed response, which increases the likelihood of success in extinguishing fires. They also have the disadvantage of high system cost, due to the cost of components with such fast response times (in milliseconds), and the fact that these units are typically built to military specifications. The tubular extinguisher system has the advantage of being relatively crashworthy since it can flex in a deforming collision and maintain its integrity to function. It does not require active detection since it can automatically initiate in the presence of a fire. It is space efficient because it can be routed through obstructed zones. The variation using dry chemical powder-based extinguishant can prevent the re-ignition of fires. The size and shape of the rupture hole that occurs in the tube to discharge the contents when it is heated is unknown. This is a disadvantage of the system because it results in a lack of control of the discharge rate of the extinguishing material.

7. Availability/Current Uses

The survey responses indicated the breadth of current commercial applications of the technologies, suggesting the extent of adaptation required for the different technologies to be used in an automotive post-crash application. This information is shown in Table 2.

Machine vision detectors currently exist only in prototype form, but have been demonstrated for military aircraft engine and dry bay compartment applications. The other detection systems are currently used in a wide variety of applications, including military and commercial vehicles.

Conventional systems using clean agents currently use halons or other new alternative extinguishants that do not exhibit ozone depletion. Systems that now use halon must rely on existing stockpiles or recycled material for their extinguishant supply, since halons have not been produced since January 1, 1994 due to environmental legislation.

Inert gas generators are planned for use in some military aircraft engine applications. Water and dry chemical-based gas generator hybrids exist only now in prototype form, and no current applications exist. Aerosol units are used in some engine compartments and computer rooms.

Foam systems are used to fight large fuel spills.

Dry chemical-based explosion suppression systems are used in industrial processing plants and in mines. Tubular extinguishing systems currently exist only in prototype form.

8. Other Issues

The particulate-based extinguishing materials, such as the dry chemical powders and aerosols, can create some level of corrosion, based upon the type of extinguishing material, the surface type on which it is deposited, the temperature of the surface and the length of time the material is left deposited on the surfaces. This time factor raises some concerns of the need for rapid clean up in the event of a non-collision false discharge. Upon contact with a fire, some powders and clean agent extinguishing materials decompose into corrosive acid gases of varying levels of concentration. This acid gas concentration usually depends upon the time required to extinguish the fire, with longer periods creating larger quantities. This is based upon the increase in thermally-induced extinguishant decomposition due to extended exposure to the fire. The storage of pre-mixed AFFF/water is problematic, with the current annual inspection requirement for these systems. The reliability of these systems over the lifetime of an operating vehicle, its serviceability by dealers and mechanics, and other questions relating to feasibility were beyond the scope of this study.

B. Passive Systems

1. General Description

In contrast to active systems, passive systems do not normally use detectors or manual devices in functioning to mitigate fires. These systems typically attempt to prevent the initiation of a sustained fire (such as crash-resistant fluid reservoirs), or manage the fire by some other means (such as flame arrestors and fuel shutoff valves). Passive systems rely on either direct impact of the device, changes detected in operating systems as a result of a collision, or direct impingement by a fire. These systems are also listed in Table 3.

The surfaces of flame arresting materials or devices can impede the progress of a propagating flame front by extracting the heat required to sustain the propagation of a flame. Valuable properties of these materials are high surface area and heat sink capacity. For example, the air cleaner filter on vehicles functions in this role by stopping the propagation of back fires through its porous, high surface area material. One currently available example with promising potential is a metallic mesh material with hexagonal cells inserted into fuel tanks to reduce the chance of severe rupture upon impact (due the resultant hydraulic ram of the fuel inside). The mesh slows or suppresses an expanding flame front within the fuel tank and retards the resultant leakage of fuel out of a ruptured tank. The material in sheet form acts as a flame barrier to block the progress of a flame front, either by being extended or coiled in a voided region or placed on a solid surface.

Reticulated foam is used in some aircraft fuel tanks, and could be placed within voided cavities. It is formed by blowing a polymeric material such as nylon, forming an expanded, compressible cellular structure. The material is porous and is not likely to impede the flow of fuel to the engine. It performs similarly to the metallic flame arrestor material, due to the high surface area of its cellular structure.

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Self-sealing fluid system components, used for fuel tank or fuel line applications, feature an outer jacket enclosing a viscous material such as natural rubber, possibly with additives. When the fluid system component is punctured, the outer jacket is also punctured, and the rubber sealing material flows into the wound to seal it and prevent any leakage of fluid. Similar materials are used inside some tires to seal holes created from punctures due to road debris.

Enhanced crashworthy fuel tanks are designed to help withstand severe impacts without the loss of fuel. The outer tank is typically made out of rigid welded steel (usually double walled) with structurally robust connectors and fittings to other fuel system components. An internal flexible rubber bladder is used to prevent leakage if the outer frame is ruptured. The bladder adds an additional barrier to puncture, and allows deformation without the release of fuel. Other features may also be present, such as a self-sealing jacket or internal layer, or automatic fuel shutoff valves in the filler neck (as in existing vehicle tanks) and outlets for fuel containment in case of vehicle rollover.

Fluid shutoff devices are used to shut off the supply of fuel or other fluids rapidly if a rupture in the system is sensed. Actuation can result from a pressure drop in a line, engine stoppage, a fire that erupts, or by an inertia switch that detects a crash. Once initiated, a valve can be set in the closed position, or a line pinched shut by use of a pyrotechnic device and a hamrner and anvil arrangement, within milliseconds. These devices can be very small, often not much larger than the fluid line itself. Fuel pumps on existing vehicles are currently designed to shut off in the event of engine stoppage or a rapid deceleration due to a crash.

Powder panels are thin hollow panels, typically between one tenth to one half of an inch in thickness, that are filled with dry chemical fire extinguishing powder. The panels can be made of aluminum sheet or extruded plastic. The panels have an internal structure constructed of aluminum honeycomb or ribbed material, designed to give the panel rigidity and prevent the powder from shifting. These panels are mounted on the exterior surfaces of a fuel tank or other fluid reservoir. When the fuel tank and the panel are punctured in a collision, the released cloud of extinguishing powder can extinguish fires in the proximity of the tank or prevent ignition.

Engine shutoff devices are electrical circuit controllers that shut off electrical power to the ignition system, fuel pump and other items required to keep the engine running. These devices can be triggered manually, by a fire detector or by an inertia switch. This feature may also be integrated into the existing automobile control circuitry.

2. Application Areas

Flame arrestor material can be used within the fuel tank. Manufacturer literature suggests its use in the vapor canister, and claims successful prevention of canister rupture in their tests. There are no empty compartments within the vehicle where the placement of this material would strategically stop the progress of a flame front. It could be used on the front and rear bulkheads, however, and underneath the floor pan. Depending on the crash circumstances, this placement could mitigate the progress of the fire into the passenger compartment.

Reticulated foam would be used solely within the fuel tank in this application. Some special types of rigid foam could be used in empty compartments to retard the propagation of fire, but there are no empty compartments that pose a threat.

Self-sealing materials can be used on the fuel tank and fuel lines, but can also be used in other applications if their benefit is shown to outweigh their cost and weight. It would be possible to manufacture jackets with self-sealing material to cover other fluid system components, such as the brake master cylinder, brake lines, oil lines and power steering fluid reservoirs.

Similar features to the enhanced crashworthy fuel tanks could be designed around other fluid system reservoirs, such as the master cylinder and power steering reservoir, in addition to its fuel tank application. Only the fuel tank application was considered in this evaluation.

Fluid shutoff devices could be used to reduce the risk of a post-collision fuel leak at numerous locations, since they are very small and relatively inexpensive. Possible application locations include the exit of the fuel tank or before the injector fuel rail. Other fluid systems could use the devices, including the brake, power steering and oil systems.

Powder panels could be mounted on the exterior walls of the fuel tank, or surfaces surrounding the location of the tank. It may be possible to mount derivatives of such devices on the underside of the hood.

Engine shutoff devices could be used to shut off electrical power to the engine. Such circuitry could also be used to shut off other electrical systems to prevent electrical shorting.

3. Fire Scenarios Addressed

Since flame arrestor materials can be mounted on the front and rear bulkhead to retard the propagation of flames into the passenger compartment, they have the potential of addressing numerous combustible/ignition source combinations by retarding their progress. Enhanced crashworthy fuel tanks may be able to eliminate or reduce the impulsive fuel spray associated with a collision, and therefore the probability of contact with nearby ignition sources. Reticulated foam would be limited to the prevention of friction spark-related ignition events in the rear, since it can only mitigate the sudden expulsion of fuel immediately after the crash. Powder panels either prevent the ignition of released fuel or quickly extinguish it. Self-sealing components can help address the combination of all of the flammable fluid sources against all of the ignition sources by reducing the chance for release of the fluids. Engine shutoff devices could help address ignition sources originating from the electrical system (by shutting it off), including both the front and rear, with almost every combustible material. The fluid system shutoff devices can help protect the brake and fuel lines from many ignition sources, and the power steering fluid, transmission fluid and oil from the ignition sources in the front, except the brake linings.

4. cost

Table 3 shows that reticulated foam, fluid shutoff devices and powder panels appear to offer the lowest cost options for passive systems, limited to the level of protection they provide. Multiple fluid shutoff devices would likely be required for the various fluid systems to achieve the desired level of protection. The estimated cost would need to be multiplied by the number of devices used. The cost of the powder panels can only be estimated, since they are not currently mass produced. This cost is predominantly attributable to the dry chemical extinguishant inside, for the cost of the raw materials and assembly of the powder panels should be negligible in substantial quantities. The cost of the standard fuel tank could be deducted from the estimate of the enhanced crashworthy fuel tanks, since it would be replaced by the more crash resistant version. No cost data were provided on self-sealing components, but it would depend upon the number of components having this feature and the extent of coverage along their length, such as a fluid line. The cost estimates do not include investment costs associated with manufacturing the vehicle, the costs of integrating the features into overall vehicle designs, or validation costs.

5. Weight

The weight estimates for the passive systems depend upon the volumes of certain reservoirs, such as the fuel tank and vapor canister, and surface areas, such as the front and rear bulkheads and the floor pan. For estimation purposes, a single idealized physical configuration and set of dimensions are assumed that would be representative of a typical car. Using this approach, the front bulkhead is assumed to cover a two-foot by five-foot section for a total of ten square feet. This section includes components that are mounted on the exterior of the bulkhead, for they also would be covered with any fire mitigation material, as part of the bulkhead surface. The surface area of interest in the rear application includes the rear bulkhead between the trunk and the passenger compartment, and the underside of the floor pan, up to the front bulkhead. This area is estimated to cover a five-foot by ten-foot region, for a total of fifty square feet. The vapor canister is estimated to consist of a cube with edges of six inches in length, for a volume of 0.125 cubic feet. The fuel tank is estimated to consist of a rectangular shape one-foot in width by one-foot in depth by two-feet in length, for a total volume of two cubic feet and a surface area of ten square feet. This volume should approximate the size required for a 15-gallon tank.

The flame arrestor material weight estimate of 0.6 lbs. in the front application in Table 3 includes 0.3 lbs. for use in the cavity of the vapor canister and 0.3 lbs. for use on the surface of the front bulkhead. The weight of the material is estimated to be 4 lbs. in the fuel tank, and 1.5 lbs. on the rear bulkhead and underneath the floor pan, for a total of 5.5 lbs. in the rear application. Reticulated foam is only used in the fuel tank, and requires 2.7-2.8 lbs. of compressed foam as installed in the representative tank. Enhanced crashworthy fuel tanks are expected to weigh no more than 5 lbs. over existing fuel tanks when configured for automotive use, although survey data were not provided comparing them with existing tanks. Fluid shutoff devices can range from 5 lbs. to as little as a fraction of an ounce apiece, although there may be several units used on a single vehicle. The additional weight resulting from the use of self-sealing components cannot be determined at this time. Powder panels are estimated to add approximately 7.72 pounds of weight when applied to a fuel tank such as the representative previously described. Engine shutoff devices were reported to weigh 1.0 lb. in the surveys.

6. Advantages/Disadvantages

The advantages and disadvantages of the systems are listed in Table 3. This section serves to clarify some of the items noted in the table and the assumptions made to explain them. Since the flame arrestor material can be mounted on the bulkheads, it might possibly be damaged in a crash and compromise its flame arresting capability in some circumstances. Therefore, it was not credited with a notable degree of crashworthiness for that application. Reticulated foam, however, is credited with an advantage in crashworthiness, since it is not used on the bulkheads. A possible disadvantage of some varieties of foam could be the potential for static charge to build up and discharge in the tank, causing possible degradation of the foam over time. This could result in the formation of foam particles that could clog the fuel system. Self-sealing components may have the disadvantage of only sealing limited rupture scenarios.

7. Availability/Current Uses

The flame arrestor material is described in the manufacturer literature as being useful in automobile and military system fuel tanks, vapor canisters and fire walls. It is not clear whether this material is currently being used in any of these applications. Current uses of the other technologies are listed in Table 3.

8. Other Issues

Much research is required on the performance of self-sealing materials as well as powder panels, flame arrestors, and other devices to insure successful use in post-collision vehicle fires. If a fluid line is severed and its ends are separated a significant distance or if a large hole is made in a fluid reservoir, it is uncertain if the self-sealing material will seal satisfactorily. Powder panels may also be vulnerable to damage when mounted on the bottom of the fuel tank if they are not shielded from the ground. Long term reliability in motor vehicle operating environments also needs to be assessed, as to manufacturability and integration issues.

C. Fire Resistant Materials

1. General Description

Fire resistant materials, generally engineering plastics or textiles, can reduce the severity of fire in several ways:

* they are not easily ignited.

* they are less prone to sustained burning, especially if an ignition source is removed.

* they release low amounts of heat energy when impinged by a flame, reducing their chances of igniting other combustible materials.

* they may be used as a fire barrier.

Intumescents and ablatives are special types of fire resistant materials that do not replace existing plastic or textile components, but are typically added to the exterior of surfaces. Intumescent materials impede the progress of a fire and the flow of heat through a surface by swelling when contacted by a flame or intense heat source. This expanded material structure may form a protective char on the exterior of the surface, in addition to providing an insulative capability. When impinged by a flame, ablative materials release off-gas vapors from their exterior surface that convect heat from the surface and inhibit the flame from burning through the surface. These materials are applied as a viscous coating or cladding on the outside of the surface to be protected.

2. Application Areas

Fire resistant plastics offer potential for use in current automotive plastic components, such as fluid reservoirs, ducting, conduits, fan shrouds, fuse box and component housings, wiring insulation and some tubing. The fire resistant fabrics offer potential for use under the hood, lining the trunk or for other sound or heat insulation, or as a heat shield surrounding hot exhaust system components. In this study, the fire resistant plastics and fabrics will also be considered for use on the front and rear bulkheads and floor pan as an effective flame barrier. Further analysis and experimentation will be necessary to confirm whether this application is suitable using the practical thicknesses of these products. The intumescent and ablative coatings can be used on the exterior of the front and rear bulkheads and the floor pan.

3. Fire Scenarios Addressed

The fire resistant plastics, fabrics and intumescent/ablative coatings can mitigate fire damage from all of the combinations of ignition sources and combustible materials. This is potentially achieved by reducing the risk of the propagation of fires originating from these combinations from entering the passenger compartment, when the materials are used on the bulkheads and floor pan. In addition to retarding the propagation of fires originating from these combinations, the fire resistant plastics or fabrics can also help prevent the ignition of combustible materials they replace in many applications.

4. cost

The costs for the range of material types are listed in Table 3. The fire resistant plastics reveal a wide range of cost. The lower range is due to one particular product that, although being an insulative sandwich construction of foam and aluminum foil, was classified by the manufacturer in the surveys as a fire resistant plastic. It is used as a low cost fire barrier in the construction industry. The single cost estimate received for the fire resistant fabrics was much higher, when used on the bulkheads and floor pan. If the fire resistant plastics and fabrics are also used to replace other existing components, no estimate can now be given on their cost increase over their standard counterparts. The intumescent and ablative coatings were similar order in cost to the fire resistant plastics. Cost estimates do not include investment costs associated with manufacturing the vehicle, the costs of integrating the feature into overall vehicle design, or validation costs.

5. Weight

In this analysis, the thickness of the fire resistant materials or coatings on surfaces, such as the bulkheads and floor pan, was assumed to equal 0.1 inch over the conventional materials they replaced. The primary reason for applying this constraint was the limited clearance space in the areas where they would be used. It was observed that the weight of many of the materials became very large when applied in increased thicknesses. The lower range of weight in Table 3 for the fire resistant plastics can be attributed to the insulative sandwich material mentioned previously. It was presumed that fire resistant materials, when replacing existing materials and components, as opposed to being added to the bulkheads and floor pan, would add relatively less weight to the vehicle. Furthermore, they would not affect the rating score if they weighed less than five pounds. The intumescent and ablative coatings were assumed to be applicable for use on the bulkheads and floor pan.

6. Advantages/Disadvantages

Fire resistant plastics, fabrics, and intumescent coatings all have the advantage of helping address fires that re-ignite, when applied on the bulkheads and floor pan. One fire resistant plastic product has advantages of cost and weight; otherwise, these categories might be considered disadvantages for the remaining plastics. The fire resistant fabrics can have advantages of weight (particularly in the front application), reliability and crashworthiness. Their crashworthiness is due to their resistance to tearing (such as in a crash), which would result in a compromise of their fire blocking capability. Intumescent and ablative coatings are generally crashworthy, since flexible versions exist that can resist fracture if bent (such as in a crash). If they are fractured, the intumescent varieties swell upon heating and possibly seal any crash-related fractures, although it is unlikely that they would seal holes and openings that occur in crashes.

7. Availability/Current Uses

The fire resistant plastic materials submitted in the surveys are used in the construction industry, for automotive trim and fuel lines, and computer cable jackets. Fire resistant fabrics are used in firefighters' and racing drivers' suits, automotive heat shields and hood liners. Intumescent/ablative materials are used in the petrochemical and aerospace industries, and in school bus interiors.

8. Other Issues

The effectiveness of the fire resistant plastics and fabrics, when used as a flame barrier on the bulkheads, needs further research. Such analysis should factor in a limitation of the thickness on which they can be applied to a surface. The weathering and durability of these materials in an automotive environment also require investigation.

III. FIRE INTERVENTION TECHNOLOGY RATING METHOD

A. Rating Process

A preliminary review of existing fire intervention products revealed that there are a large number of relevant products and technologies which, according to their manufacturers, are currently available and offer promise for reducing the severity of post-collision vehicle fires. Information collected from manufacturers of such products was rated using a set of criteria developed to evaluate the products' potential to improve automotive fire safety. The criteria were developed by project team members with expertise in fire safety, fire protection equipment, crashworthiness and other automotive integration issues. A major strength of the criteria was the capability to compare highly dissimilar systems and concepts on a single scale. The rating protocol was constructed based on engineering judgment and without the benefit of crash test data or field experience. Numerical values were assigned to each product or technology based on the rating system, allowing a ranking of the various products. It is recognized, however, that other considerations in addition to the rating process may be used to make decisions on the utility of given products and types, their manufacturability, and long term reliability. In addition, the rating system makes no distinctions among highly variable vehicle designs.

B. Categories and Weights

The rating criteria considered various possible post-collision vehicle fire scenarios of interest and operational issues. The criteria were designed to rate a wide range of concepts. The rating protocol was weighted to reflect the relative merit of various fire protection strategies. The protocol was broken into several categories. One-half of the total rating points was allocated to the product's capability to address front-end or rear-end vehicle fire scenarios. "Crash-worthiness" (a measure of its ability to function after a crash) was allocated 25 percent of the overall points. The remaining 25 percent were split evenly between "Product Reliability and Stage of Development" and product "Weight". An additional 5 points were added for technologies that mitigate non-collision fires. Further details on the breakout of points within each category will be discussed in the next section.

In "An Analysis of Fires in Passenger Cars, Light Trucks and Vans" (Tessmer, J., NHTSA Technical Report, DOT HS 808-208, 1994), data were reported on the number of fatal automobile accidents where fire was judged to be the most harmful event (Exhibit 30 in the cited report). The data included accidents from 1979 to 1992, with 1978 model year and later passenger cars, and was sorted by the damaged area of the vehicle or impact type. It was shown that during that period, 839 front impact fatal crashes and 270 rear impact fatal crashes occurred in which fire was judged to be the most harmful event. The rating system was designed to reflect these statistics. Other collision scenarios such as side impacts and rollovers were not considered.

Within each of the fire intervention areas (front and rear), the breadth of fire scenarios addressed by each product was assessed. This was achieved by awarding points for each fire scenario addressed by the product that involved a particular combination of a fuel type and ignition source (with “fuel” defined as any combustible substance). Defining the different fire scenarios by these combinations was an effective way to assess the merits of very dissimilar concepts. The combinations of fuel types and ignition sources that can be addressed by different types of technologies are generally recognized (as shown in Table 2). In addition, this approach was able to capture many of the diverse intervention techniques used by the various technology types to give proper credit to their merits. As an example, fire resistant barriers (on the front bulkhead) might help address fires from a wide variety of combinations in the front. A fire resistant plastic, however, only replacing existing components, will help address only fires involving solids with electrical shorting and hot surfaces. Only those combinations that were relevant to front and rear fires were included in the protocol. Points were earned for each of the combinations addressed; thus, products addressing more scenarios received more points. This feature was important for products such as fire extinguishers, where the points allocated for their wide range of scenarios addressed could properly balance their possible negative attributes in weight and crashworthiness.

The rating protocol was weighted based upon whether a technology could prevent ignition of the fire, extinguish the fire or simply retard its progress for each of the fire regions and fuel/ignition combinations. The largest number of points was assigned to ignition prevention, followed by extinguishment, and finally retardation of fire spread. Retarding the fire’s progress can offer value by buying time for the occupants to evacuate or be rescued, the fire to be extinguished by emergency personnel or the fire to die out by itself. The points accorded to these three options were distributed in a ratio of 5:4: 1 respectively. The points attributed to fire extinguishing were split between the first initial knockdown and extinguishment of the fire, and the subsequent capability to prevent re-ignition.

The rating system considered crashworthiness based upon various features or traits of a technology that would promote its ability to remain functional following a crash. The highest rated feature was the capability to be activated by the crash itself and provide sustained protection. Technologies that offered such a capability were entitled to all of the points in this category.

Although this program is focused on technologies that might help address post-collision fires, the potential of a technology to mitigate non-collision fires would also be of value. A small amount of points were awarded for this capability.

The category “Product Reliability and Stage of Development” addressed the probability that a product can evolve to meet required performance objectives for automobile use. This was quantified by a product’s current applications and projected capability as it relates to post-crash vehicle fires. The allocated points diminish with the reduced level of relevant development, from current use in vehicle fire protection to only being a theorized concept.

The category “Weight” awarded points based upon the expected weight of the technologies as installed, with the lowest weights receiving the most points. A broad range of four weight bands was used.

Cost was not included as a factor in the rating process. It is premature to realistically assess the cost of technologies. The goal of this project was to assess the potential for these technologies to contribute to the post-collision fire safety of passenger vehicles, regardless of economic considerations.

In summary, a rating protocol was established that assigned 100 points (plus five bonus points) to the various areas of interest related to the use of fire intervention technologies on automobiles. The categories were arranged as follows:

1. Fire Suppression Capability (50 points)
   a. Front-End Fires Addressed (37.5 points)
   b. Rear-End Fires Addressed (12.5 points)

2. Crashworthiness and Effectiveness after the Crash (25 points)

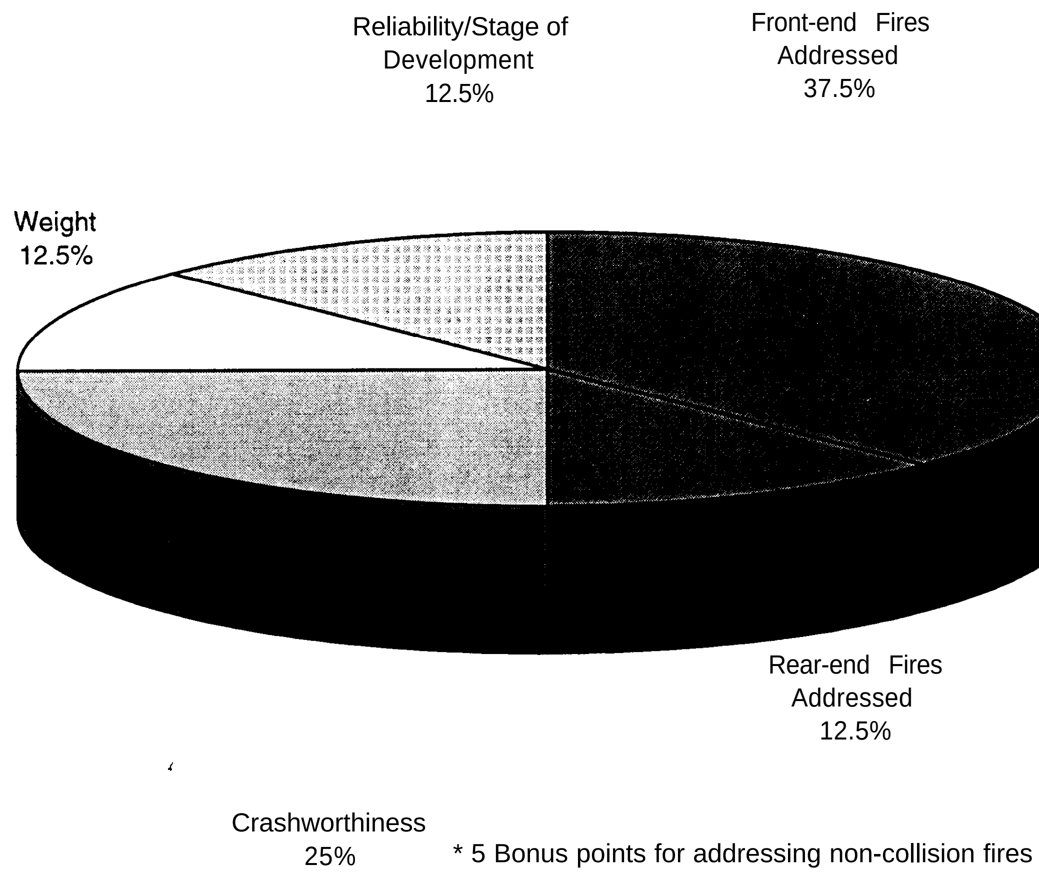
3. Effective for Use on Non-Collision Fires (5 Bonus points)

4. Reliability and Stage of Development (12.5 points)

5. System Weight (12.5 points)

This allocation of point values in the rating is illustrated in Figure 1. The complete layout of the rating protocol and a detailed description of assigned point values for limits of capability within each category are contained in Appendix C.

FIGURE 1 - TECHNOLOGY RATING POINT ALLOCATION



IV. RESULTS AND IMPLICATIONS

A. Overall Results

The results of applying the rating protocol to the products submitted in the returned surveys are shown in Table E- 1 in Appendix E. Table E- 1 is organized by technology category, i.e., active systems, passive systems, and fire resistant materials. Each product has three entries associated with its rating for use on the vehicle front, rear or both in combination. The estimated product weights and point scores are listed. The Assumption numbers in the table are consistent with the numbering in Table D-l in Appendix D. This section will briefly discuss the rating results.

The detector options chosen with each active system are noted by a code letter in the column after the technology name in Table E- 1. This code letter is consistent with the detector code letters associated with the detectors that are listed first in the table. If no letter is noted in the column, then active detection apart from that already integral to the extinguishing system was not required.

* For extinguishing systems without existing integral initiation means (such as a frangible sprinkler bulb or manual cable), the linear pneumatic/spot detector combination system was usually the best rated detector option. For systems with at least one integral initiation means, the linear pneumatic detector typically provided the best supplementary choice at a lower weight (and corresponding higher point total).

* Those extinguishing systems that used dry chemicals, aerosols, AFFF or water mist earned significantly more points under “Fire Scenarios Addressed” than the clean agents and inert gases. All of the active systems were also determined to be usable in non-collision fire scenarios.

* Among the passive systems, the self-sealing fluid systems and fluid shut-off systems were the highest ranked.

* The fire resistant plastics and fabrics were rated in two configuration options - either only replacing existing materials on the vehicle, or also being applied to the bulkheads and floor pan - with the highest rated option selected. As can be seen in Table E- 1, the preferred arrangement varied between different materials, and even between different application areas of a particular material. The decision whether to add bulkhead protection or not was a trade-off between the additional scenarios addressed in retarding fires versus the increased weight.

B. Ranking

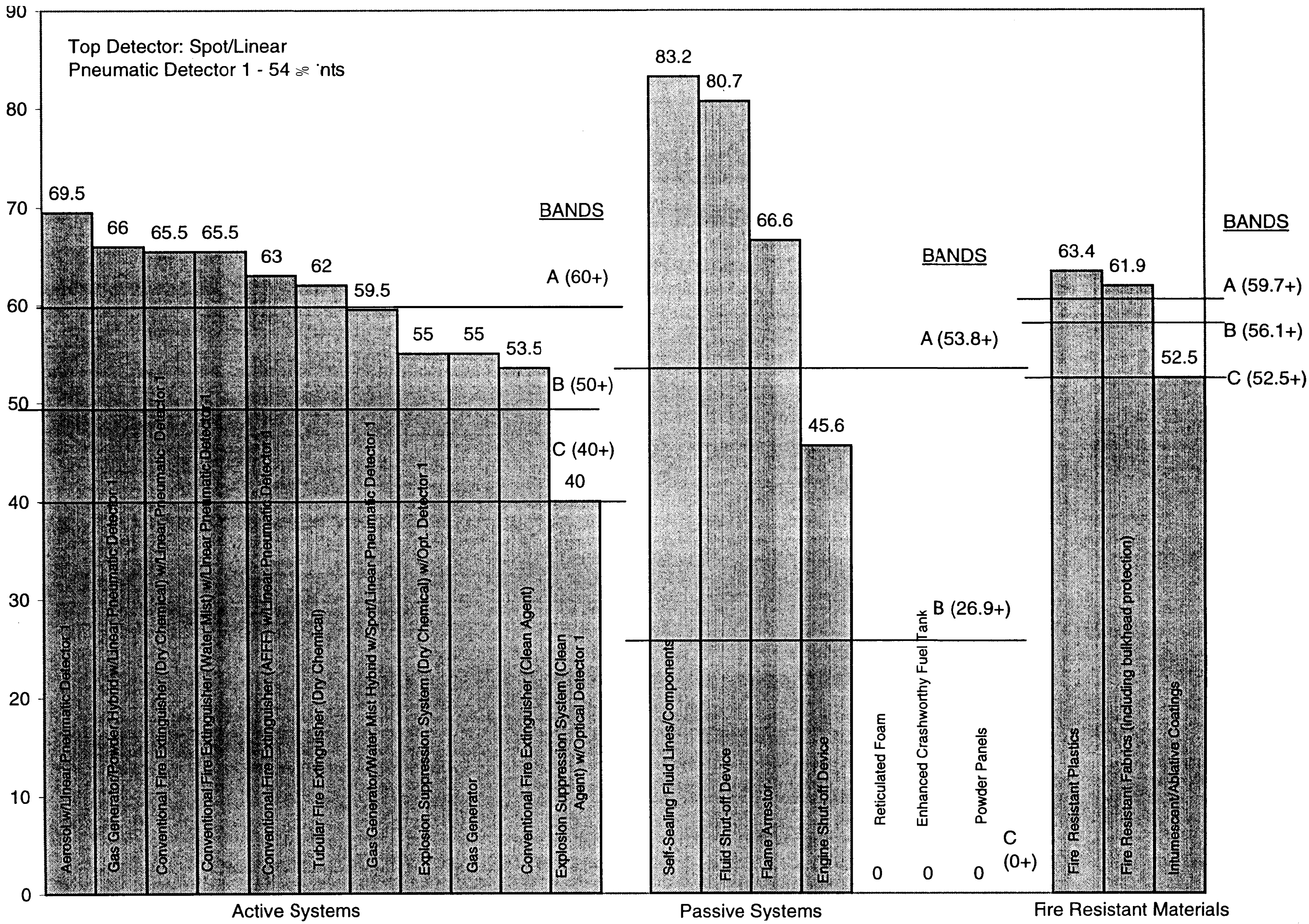
The results of the survey and rating process were evaluated by developing a prioritized list of technologies for each application area. This list was ranked by the rating point values of the technology types using a representative product receiving the highest value for each type. For example, if three products represented reticulated foam, the point value of the one which was highest in that application area of interest was listed in the ranking. This number was compared to similarly evaluated top-scoring products of the other technology types. Since many of the final point values were within a few points for many technology types, it was decided to express their rankings in a series of broad bands (denoted A, B and C). This approach was intended to mitigate over-interpretations of the limited data due to unknown information and the assumptions required in the evaluation. The relative scores of products within a band may be considered roughly equivalent. It was subjectively decided to split the bands into three equally spaced point ranges, by dividing the range between the highest and lowest point values within a category and application area by three. This did not usually result in the same number of technology types in each band, but demonstrated how the ratings of the types congregated and formed natural “pools” of performance. These “pools” are observable groupings of similarly rated technologies. They subjectively suggest some level of difference in the potential of the various groups of technologies to satisfactorily meet automotive fire safety and other requirements.

B1. Front Only Application

A ranked listing of the rating point values of the top-rated products representing each of the technology types is shown for the front application in Figure 2. These listings are separated by the three technology categories. For the active systems, the particular detector matched with a system to give its highest score is also listed with it. If a detector is not listed, then its innate activation means (e.g., autoignition at set temperature thresholds) produced the highest valued configuration.

For the active systems, the first obvious observation is the large number of technology types in Band A. All of the products in the A band use extinguishants that were assumed to prevent re-ignition. This feature was a large factor in the high ratings within a very tight range, in comparison to similar products that don’t prevent re-ignition at the bottom of this category. Thus, the value given re-ignition prevention serves as a key discriminator. The validity of this value should be confirmed by real-scale vehicle fire tests. In addition, the top two rated technology types were the only ones that featured weights low enough to be placed in the highest point band under “Weight” (5 lbs. or less). This was due to their being normally non-pressurized systems. The aerosol system emerged as the highest rated system due to its high level of development in other applications. The conventional system products that follow next on the list benefit from current usage on highway vehicles. The main advantage of the tubular system was its higher crash-worthiness by being flexible. The remaining systems had higher application densities and weight requirements, a lack of re-ignition protection, or limited crashworthiness features (such as multiple activation means).

FIGURE 2 - SUMMARY RATING OF TECHNOLOGY TYPES (FRONT ONLY)



When evaluated independently, the combination spot and linear pneumatic detector was the top rated detector system. It featured the most crashworthy features, is currently used in vehicle applications and has moderate weight.

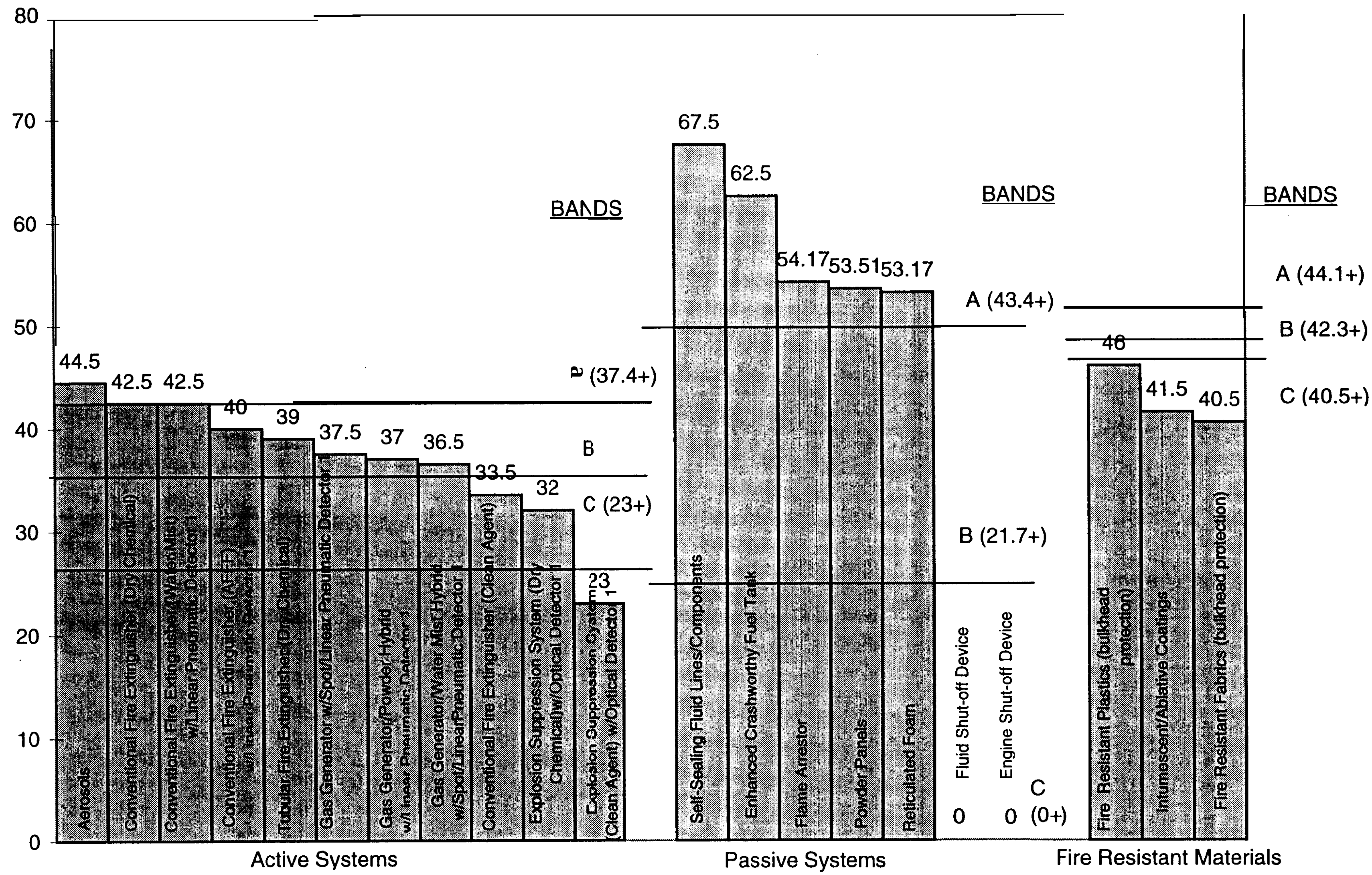
Among the passive systems the self-sealing fluid system components and fluid shutoff devices were rated above the other products. The flame arrestor material also falls into B and A, although it is well behind the first two options. The self-sealing fluid systems benefited from numerous advantages. They include no presumed weight increase, the high value of preventing fires by fuel starvation, activation by the crash itself and current use in vehicles such as law enforcement. The fluid shutoff systems also share many of the same benefits, as they perform the sarne task; namely, preventing a fire or starving it by preventing or greatly reducing fluid release. This protection scheme is enhanced by placing numerous shutoff devices at various locations in the fluid systems to minimize drainage and improve reliability. The lightest weight varieties (such as those which have the pyrotechnically-driven line-pinching feature) may need to be further developed to optimize them for automotive use. The flame arresting material benefits from very light weight due to its low density in mesh form and its general crashworthiness due to its simplicity (except for tearing when used on a bulkhead). It also has a wide breadth of potential application, being usable on both the front and rear bulkheads, and in the fuel tank and vapor canister. In Band B, the engine shutoff system has some features in common with the fluid shutoff system. Since it is an electronic system, however, it is limited in scope to shutting off the fuel flow and some electrical systems, whereas the fluid shutoff system can be used to stop the flow of any of the flammable fluids (thereby addressing more fire scenarios). The system as now designed is triggered by an extinguishing system, but wiring it to an inertia switch may be possible, which would improve its crashworthiness. The enhanced crashworthy fuel tanks, reticulated foam and powder panels received 0 points for the front application since they are only expected to be used in the rear area (see the Summary for the implications of their mitigation of possible rear fuel spillage due to frontal impacts).

The top fire resistant fabric and plastic were ranked roughly equally, although the fabric considered for use on the bulkheads and the plastic was not in this application. The increased range of scenarios addressed by the fabric on the bulkheads was almost completely offset by the reduced crashworthiness, as it was vulnerable to tearing in that role. Plastics have been used in fire resistant applications in the automotive industry, whereas the fabric was limited to prior automotive heat shield uses. The best intumescent/ablative coating was rated somewhat less, due to its limited role in retarding fires and higher weights when applied to the bulkheads.

B2. Rear Only Application

There are two notable features concerning the rankings in Figure 3. First, the rankings are uniformly lower than in Figure 2, reflecting the lower weighting for the rear fire scenario. Second, for the active systems, the ranking appears almost identical to those in Figure 2, with the exception of the gas generator/powder hybrid. The gas generator/powder hybrid exists only as a theoretical concept, whereas the other technologies in Band A all exist at a higher level of development, including the conventional gas generator. With the exception of the gas generator, the capability to prevent re-ignitions was also an important factor in the ratings. Note that in

FIGURE 3 - SUMMARY RATING OF TECHNOLOGY TYPES (REAR ONLY)



some cases the detector pairings are different from their configuration for front applications. As noted earlier, this was done to achieve the highest point total.

By contrast, there are considerable changes in the relative scores of the passive systems between Figures 2 and 3. These changes are logical, given their location- and application-specific nature.

The fire resistant plastic received more points in the rear than the other two fire resistant material types due to lower weight, which was 15 to 30 lbs. less than the others when applied on the rear bulkhead. The other material types had more crashworthy features to their credit.

B3. Front/Rear Combination Application

In this subsection, technology types are rated for use on both the front and the rear of the vehicle (as shown in Figure 4), with each technology simultaneously used in both application areas (when feasible). Using the same technology in both areas may not always give the highest score, and in many cases a combination of different technologies or simply ignoring the rear area gives the highest score (due to weight impacts), but for consistency this protocol was followed. This may be a preferable option in terms of reliability and system and installation costs, and if not, the data from the single application areas can suggest more optimal configurations for further study.

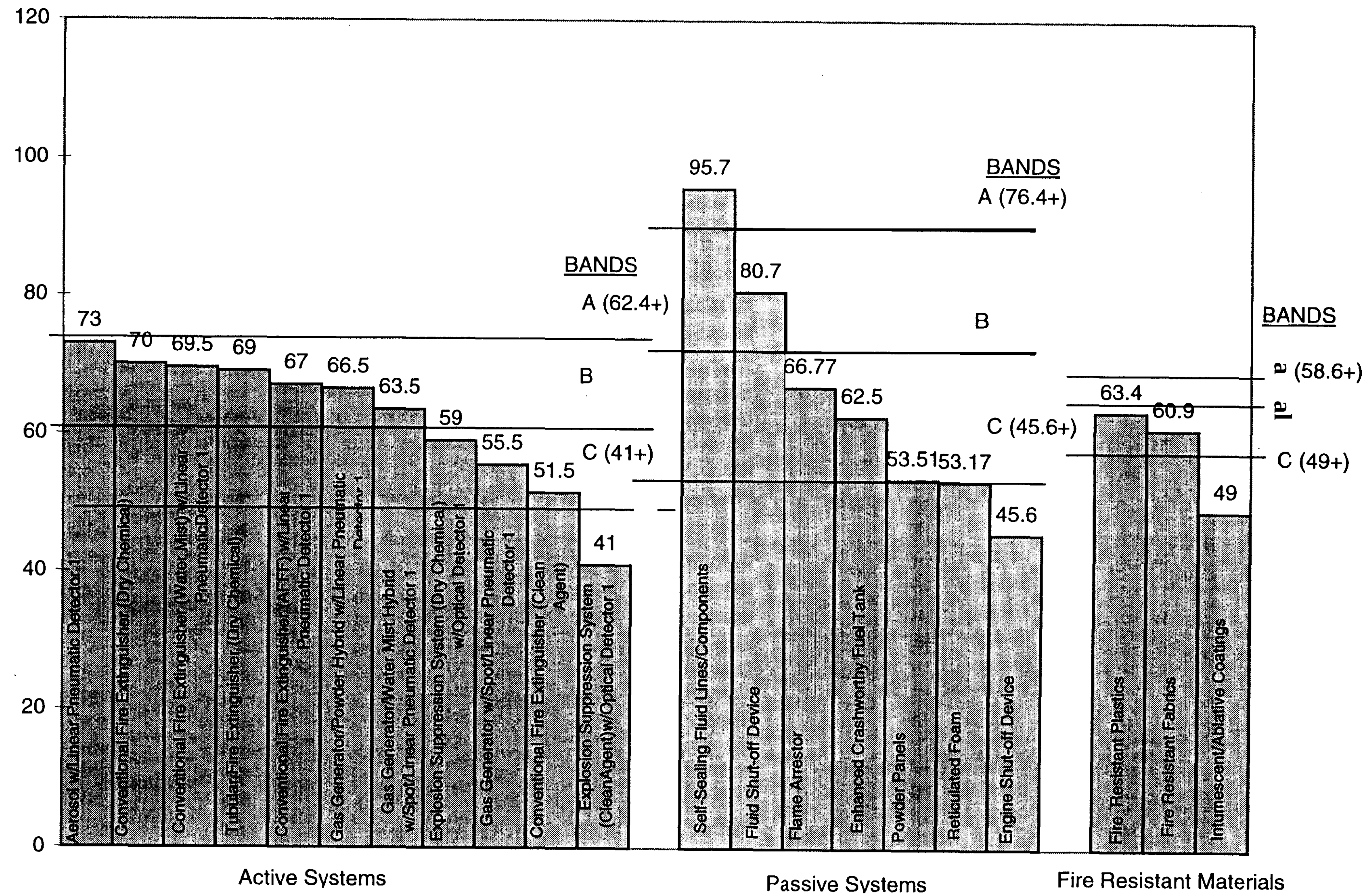
As expected, the results for the active systems are nearly an average of the front and rear rankings. Among the passive systems, the self-sealing fluid system components and fluid shut-off devices dominated the other technologies in scoring, due to their fire prevention capabilities and their minimal weight. The difference between the two component types can be attributed to the lack of application of the shut-off devices in the rear. The only notable feature in the set of fire resistant materials is the increased spread of the intumescent/ablative coating scores from the other two product types. This was due to the high weight penalty incurred. Had the weights of these coatings been less than five pounds, then their score would be comparable to the other materials.

C. Summary

The most compelling findings are as follows. It should be remembered that these results reflect the inherent limitations of the rating system and require verification.

1. The self-sealing fluid lines/components and fluid shutoff devices appear promising. The self-sealing material and the shutoff devices have several advantages, including the prevention of many types of fires in the front area (and also the rear area for the self-sealing material), utility in non-crash events, and a high degree of crashworthiness. In addition, they have been used in some automotive and other vehicle applications and are relatively low in weight. The number and placement of fluid shutoff devices required to maximize effectiveness needs to be determined.

FIGURE 4 - SUMMARY RATING OF TECHNOLOGY TYPES (FRONT/REAR COMBINATION)



2. The active extinguishing systems with extinguishants that provide re-ignition protection could provide significant benefits. These products are complementary to the passive systems by addressing additional scenarios that the passive systems do not. They also are potentially useful in non-collision fires, have a wide range of crashworthy features and a track record in extinguishing fires in some special vehicles, such as municipal buses. Questions remain about their level of performance. These include their capability to extinguish reliably at the estimated design quantities, their degree of crashworthiness, and the magnitude of their weight and space penalties. The value in the rating system attributed to re-ignition prevention (which contributed to their high rating scores) would need verification in realistic vehicle bum tests to assess the likelihood of such re-ignitions and the importance of its prevention.

3. Among the extinguishing systems, very little differentiates the performance of many of the best extinguishant/hardware types, within the limitations of the rating process. With the exception of the aerosol system, which benefited from much lower weight, the top six technology combinations (all with re-ignition protection) had similar ratings. Some of the technologies, such as the tubular, aerosol and gas generator systems may prove to be more crashworthy, but this requires further study. The goal of discriminating among these technologies may not have been achieved satisfactorily by the use of this rating process. Further crash and fire extinguishing tests will be necessary to determine the most promising candidate, possibly factoring in other issues such as space requirements and cost.

4. Among the fire resistant materials, the fire retardant plastics and fire resistant fabrics had similar ratings. The fire resistant fabrics and plastics rated somewhat better than the intumescent coatings. However, either the assumption of no weight impact for component substitution and/or the assumption that they can be used on the bulkheads may not be correct. Measurements are needed on these materials to test these assumptions.

5. In the rear application, the well-rated passive technologies (in addition to the self-sealing fuel system components) may provide substantial benefits, and may be superior to the active systems, as suggested by the ratings.

6. The flame arrestor material may be a promising technology for use in both application areas, if used in the vapor canister and on the bulkhead, as well as in the fuel tank. Both of the front-end applications, however, are questionable in terms of their expected success, in contrast to the more traditional application within a fuel tank. If shown to be effective, it offers another passive, crashworthy and space-efficient technology for potential use in the front area (at reasonable cost and weight).

7. The explosion suppression systems and conventional clean agent fire extinguishing systems do not appear to offer any tangible advantages in this application. The lack of re-ignition protection in the conventional systems and the lack of variable initiation means and expense of the explosion suppression systems handicap these systems severely.

8. The best-rated fire detector was the linear pneumatic detector. This detector was very lightweight, rugged and very crash resistant. It should be considered as an option for all of the active systems. The combination of the linear pneumatic with spot detectors gives the detection system multiple activation means at moderate weight. This is the arrangement of choice for extinguishers requiring active detection. Some extinguishing systems already have their own integrated detection and/or initiation systems, so inclusion of these detector options is not necessarily advantageous. They must first be studied to determine if the additional features and benefits they offer are not redundant or are offset by increased cost and weight.

9. Special scenarios resulting in fuel tank rupture due to frontal impacts were not considered but can occur, and can effect actual rating scores somewhat if included. Fuel tank ruptures can occur due to specific crash circumstances such as drive shaft penetration into the fuel tank, or rupture or tearing of the tank from its fuel line fittings due to the inertia of a tank containing sufficient fuel during the sudden deceleration in a frontal impact. These events were observed in full-scale auto impact experiments, and are presumed to occur in the field in some instances. If so, the fuel may ignite due to the sparks resulting from fuel tank impact or fuel contact with ignition sources in the rear. The fuel may also spread to the front and initiate a fire if in contact with frontal ignition sources, or increase the severity of an existing frontal fire. The consideration of frontal fires, rear fires or both due to frontal impact requires some liberality of interpretation of the first two rating categories. This special scenario does not result in the presumed occurrence of frontal fires from frontal impacts, or rear fires from rear impacts, as with the other scenarios. The reinterpretation of these categories includes the consideration of any fires (front or rear) created from either frontal or rear impacts. In addition, it includes the consideration of fuel released from the tank due to frontal impact spreading to the front of the car to support a frontal fire (consistent with the other scenarios considered) and results in the same adjusted scores in either case. The three passive technologies affected are the enhanced crashworthy fuel tanks, powder panels and reticulated foam. This resulted in revised scores for the enhanced crashworthy tanks of 64.1, 62.5 and 76.6 for the front, rear and front/rear respectively as opposed to 0, 62.5 and 62.5 previously. Revised scores for the powder panels for the front, rear and front/rear were 55.1, 53.51 and 67.61 as opposed to 0, 53.51 and 53.5 1 previously. Scores of 54.77, 53.17 and 67.57 for the front, rear and front/rear using reticulated foam as opposed to 0, 53.17 and 53.17 previously were calculated. The scores for the rear area are not affected. For the front area, the enhanced crashworthy fuel tanks move from Band C to Band B. This is due to the adjustments in the bandwidths resulting from the new minimal score of 45.6 for the passive technologies, which moves the Band A threshold to 70.66, and places the front/rear score at the threshold of Band A. The powder panels would remain just within the revised Band C for the front application, and within Band B for the front/rear application.

V. RECOMMENDATIONS

Based upon the results from the survey of available fire protection technologies with potential for automotive application, the following recommendations can be made:

1. The assumptions used in the rating process, and the performance data specified in the manufacturer's responses should be screened at laboratory scale and, as appropriate, verified in vehicle crash and fire tests and field data. Several examples of key assumptions and data to be verified are listed below:

* Verification of the performance of the fire resistant fabrics, plastics, flame arrestors and intumescent/ablative coatings as applied on the bulkheads, particularly in terms of thickness needed for the desired level of protection.

* Assessment of the maximum area of surface damage and distance of severed fuel line separation that a self-sealing jacket can seal, the required sealing duration, and the weight of material required to accomplish

* Confirmation of the mass requirements for the different extinguishant/hardware combinations, as a function of different vehicle fire types, extinguisher and discharge locations and time of initiation. In addition, consideration should be given to the effects of damage and deformed structure, deposition of the extinguishant, and degree of reliable distribution capability and coverage, including ventilation around and through the compartments.

* Verification of the performance of the rear fuel tank technologies; specifically, their capability to prevent fuel tank rupture, slow the immediate and long term release of fuel, and/or the potential to locally inert against fire initiation (for the powder panels).

* Verification of the crashworthy features offered by the different technologies, including flexibility, operability when damaged, high g-load resistance, multiple activation means and long term protection after initiation.

* Determination of the response times of the fluid and engine shutoff systems verified, as a function of differing vehicle designs, differing conditions and flow rates, pressures, etc.

* Determination of the bum-through characteristics of the tubular extinguisher, as a function of temperature, flame proximity, etc.

* Assessment of the damage healing capability of intumescent/ablative materials as they swell, and a determination of whether they seal fracture seams and holes.

* Confirmation of the potential for gasoline and other fluids to ignite on hot surfaces of operating automotive components under normal conditions, and its effect on the performance of the mitigation technology.

* Assessment of the post-crash survivability of fire detectors, including the impact shock resistance of frangible bulbs (used in extinguishers) and spot detectors, and the potential for linear thermal detectors to short circuit when severely crushed or severed in a crash.

* Determination of the merits of a “smart” active extinguishing system that can be directed to either the front or rear of the vehicle, with the benefits of reduced

  coverage.

*

  improvements to the performance limitations of the low expansion variant.

* Experimentation to assess the potentiality and ramifications of fuel tank rupture due to frontal impact, either from drive shaft penetration or fuel tank inertial dislodging. The potential of the fuel to be ignited in the rear area, either instantly or after contact with rear ignition sources, and its ability to spread to the front of the car, either already ignited or when it contacts frontal ignition sources, are recommended for inclusion in the investigation.

2. Hybrid configurations featuring several technologies are recommended for study to determine the optimal combination of technologies and features to maximize the fire mitigation potential with minimal penalties.

3. Self-sealing fluid system components, fluid shut-off valves, aerosol systems, conventional dry chemical extinguishers, gas generator/powder hybrids, tubular extinguishers, and linear pneumatic detectors are recommended for further consideration.

4. Active extinguishing systems using re-ignition preventing extinguishants, crash resistant fuel tanks, powder panels, flame arrestor material and reticulated foam are recommended for further investigation, for their performance closely follows that of the technologies given highest priority and could be best under certain circumstances and applications.

5. If fuel tank ruptures due to frontal impacts are shown to be a significant concern, then the passive technologies identified as having potential to mitigate this possible fire event are recommended for further study to assess their capability in this scenario.

6. Other criteria, such as reliability, maintainability, repairability vehicle assembly impact, space requirements, safety, and cost are expected to be factored into these analyses.

APPENDIX

APPENDIX A: SURVEY LAYOUT

This appendix is a listing of the product surveys provided to and returned by the manufacturers, along with other items in the survey package. It is followed by a description of the rationale for the data requested in the surveys in Appendix B.

Two letters accompanied the survey package sent to the manufacturers. A cover letter was prepared, explaining the overall purpose of the program and project, and the purpose of the surveys. An accompanying letter was prepared by the National Highway Traffic Safety Administration, explaining the overall government interest in the program, and their long term goals of improving the fire safety of passenger vehicles and realistically assessing the viability of products currently available. The purpose of the DOT letter was to assure the participants that the endeavor was a legitimate attempt to assess their products for a potential use.

An instruction page was attached that gave detailed instructions to the survey recipient on how to respond to the survey. It also assisted them in interpreting the different survey types in the package and their relevance to a particular company's products. It listed directions for evaluating multiple product models, a brief explanation of the purpose of the project and survey, and the due date for return of the surveys. Requests were also made for additional photographs, brochures or other promotional data on the products, and for the return of the surveys even if time did not allow a complete response to all the questions. This instruction page was added separately from the cover letter. A table of contents and separate page numbering of the individual surveys was added to prevent confusion.

1 September 1996

Dear Manufacturer,

General Motors (GM) has initiated a five year research program that will investigate collision-induced passenger vehicle fires. This program will be conducted under the auspices of the U.S. Department of Transportation. As a facet of this program, technologies that will prevent or mitigate the threat of such fires to the occupants will also be evaluated for effectiveness and practicality for on-board automotive use. A number of technologies will be evaluated and demonstrated in small scale and potentially full scale automotive-type fire tests. An explanatory letter concerning this program from the Department of Transportation is attached.

I am assisting GM by providing guidance on determining which technologies and products have potential for automotive use. These technologies can be rather broad in scope in their contribution to mitigating the fire threat, of which fire extinguishers, fire detectors, fire resistant fluids and materials, flame arrestors and reticulated foams, explosion suppression systems, fuel shutoff devices and self-sealing fuel components are examples. A series of surveys have been established to determine which products and technologies exist and to collect quantifiable data on their performance, weight, cost and other issues. From this data, the products submitted in the surveys will be reviewed and considered with respect to their merits in the above issues.' The products determined most promising for automotive use will be evaluated further with current plans specifying fire tests to determine if the use of such products on passenger vehicles is promising.

The surveys with explanatory instructions are included in this package. Separate surveys exist for each category of technology. An earlier review of available technologies and manufacturers identified your company as a potential supplier of one or more of these technologies (even if they may not be currently marketed for such use). Please review the content of each of the surveys, and determine which of your products could be relevant to one or more of them. Make copies of the surveys and distribute them amongst the sales and technical specialists in your company that can answer the questions in the surveys, either using existing data or estimating answers under the conditions that the surveys request. Make a separate survey submittal for each significantly different model or product offered by your company in each category. Mail the completed surveys to the name and address listed below. It is requested that the surveys be received at that address no later than 45 **days** from the date of this letter.

It is understood that this activity will take some measure of time; it is intended, however, to generate data that will be used to seriously evaluate the potential of these products for use in this new application. Considerable resources are being expended in this program to evaluate such products, and the results are expected to be a landmark effort in addressing this safety issue. Please feel free to call the recipient at the telephone number listed below for any clarification as to the interest in your products or the intent and content of the surveys. If you do not reach me by phone, please leave a message with a date and time to contact you. Thank you for your support in this important effort.

Sincerely,

J. Michael Bennett, (513) 236-1957
GM/DOT Vehicle Fire Protection Technology Survey
P.O. Box 552, Fair-born OH 45324-0552

1 Attachment
1. DOT Letter

INSTRUCTIONS FOR SURVEY OF VEHICULAR FIRE SAFETY TECHNOLOGIES

This survey is designed to identify and evaluate technologies that may potentially improve fire safety on passenger vehicles of the future. A subset of the technologies described in the compiled surveys will be evaluated further by General Motors, including possibly some bench-scale and full scale tests either on a vehicle or in a realistic vehicular fire environment. This survey will serve as a means to evaluate and select the most promising technologies for further consideration. The data requested will function as the criteria for assessing the relative merits of the technologies. For this reason, it is critical that respondents provide information that is as complete and as accurate as possible.

To be considered for use in post-accident vehicle fire protection, the technology must be able to be packaged as a self-contained transportable system.

The types of technologies under consideration have been separated into categories that have common technology features and issues. Since the data required are specific and pertinent to each category, separate surveys have been created for each. The categories comprise the following: Conventional Fire Extinguishers, Non-Conventional Fire Extinguishers (such as gas or aerosol generators, tube delivery systems, and explosion suppression systems), Fire Detectors, Fuel Shutoff Devices, Self-Sealing Fuel Lines and Materials, Powder Panels, Flame Arrestors and Reticulated Foams, Non-or-Less Flammable Fluids, Intumescent/Ablative Coatings and Exhaust Wraps, Fire Resistant Plastics, Fabrics and Other Materials, and Other Technologies (which serves to collect data on any potential technology not categorized above).

Please fill out the surveys on each discrete product and model in your product line that is defined in the above categories. Make photocopies of the surveys for those categories in which multiple products are available, and complete one for each; surveys which do not apply to any products offered by your company may be discarded. Please distribute the surveys to the most knowledgeable product specialist (either sales or engineering) in your company for each of the relevant products for survey completion. Brochures, photographs, diagrams or drawings of the products would also be helpful, if available.

Due to the severe time constraints assumed on all parties who may respond to this survey, it has been designed to require the minimum time possible to collect the necessary data. Please make every effort to complete the entire survey for each product; each item will play a role in assessing the products' potential. If some data are too difficult to obtain by the deadline period, the surveys should be forwarded before the deadline with as much information as possible; further elaborations and clarifications may be pursued by the reviewer if necessary.

Any questions can be directed to the points of contact on the cover letter.

The deadline for receipt of the surveys is ____________.

Thank you very much for taking the time to support this important effort.

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SURVEY

CONVENTIONAL FIRE EXTINGUISHERS

(Please fill out one copy of this survey for each significantly different model)

NAME OF SYSTEM ____________________

COMPANY NAME ____________________

CONTACT PERSON/TELEPHONE NUMBER ____________________

GENERAL INFORMATION

BRIEF DESCRIPTION OF SYSTEM ____________________

____

____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

BASIC COMPONENTS OF THE STANDARD SYSTEM (Check relevant box, then specify any details on following line)

Cylindrical Bottle ________ Spherical Bottle ________ Mounting Brackets ________

Automatic Valve Manual Valve ________ Distribution Tubing ________

Remote Activation Means ________ Nozzles ________

Other Components ____________________

VARIATIONS/OPTIONS OF SYSTEM (Check relevant, then specify on following line)

Remote Activation ________ Nozzles - Variations ________

Automatic Valve ________ Other ________

CURRENT USES OF SYSTEM IN APPLICATIONS ____________________

____

INSTALLATION PROCEDURE FOR VEHICLE APPLICATIONS ____________________

____

INSTALLATION TIME 15 MIN **30 MIN** 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST (wholesale)			LOT SIZE (COST PER EACH)	
	1	1000	10,000	100,000	1,000,000
STANDARD SYSTEM:	-	-	________	________	________
VARIATIONS/OPTIONS:					
________				________	________
________				________	________
________				________	________

ESTIMATED MEAN TIME BETWEEN FAILURES OF SYSTEM (Check One) - Assume Functional During Vehicle Operation Periods
Less than 1 year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

MAINTENANCE SCHEDULE (Check One)
Every Year Everyl. l-3 years Every 3.1-5 years Every 5. 1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One)
No Cost $0-$10.00 $lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

SYSTEM DIMENSIONS (Container and Valve)
______inches x _____ inches x _____ inches (rectangular volume enclosing system)

SYSTEM STORAGE VOLUME (Container and Valve) __________________ cubic inches
SYSTEM STORAGE WEIGHT (Container and Valve) __________________ lb.
DISTRIBUTION SYSTEM WEIGHT (assume 10 ft.) ______________ lb.

WHOLESALE COST OF REPLACEMENT PARTS (fill in blank)
bottle ______________________ distribution tubing (per foot length) ___________________
nozzle ______________________ remote cable (per foot length) _______________________
recharge bottle (including o-rings, agent cost, other) ____________________________________

TYPES OF FIRES ADDRESSED (Check all relevant)
CLASS A (cellulosic, textile materials) CLASS B (liquid fuels)
CLASS C (electrical equipment) CLASS D (burning metals)

engine compartment fuel tank exterior fuel tank interior
passenger compartment underneath vehicle fuel dripping on hot surface

spraying fuel fire liquid fuel pool fire fuel vapor explosion

ESTIMATED LIFE OF PRODUCT AS INSTALLED (Assume not activated/recharged-Check)
Less than one year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

NOTE:(exclude detectors and distribution hardware (non-storage) from next two questions)
CUBIC FEET PROTECTED VOLUME PER CUBIC FOOT OF VOLUME OF SYSTEM (e.g. 1 cubic foot extinguisher system protects 1000 cubic feet of space--1000 protected cubic feet/extinguisher cubic foot)
100-300 301- 600 601-1000 1001 - 1400 1401 - 3200 3201 -4000 4001 or more
CUBIC FOOT PROTECTED VOLUME PER POUND OF SYSTEM WEIGHT (e.g. 10 lb. total weight system protects 250 cubic feet of space; 250/10 = 25 protected cubic ft./extinguisher lb. weight)
0 - 5 5.1 - 10 10.1 - 17 17.1- 25 25.1 - 35 35.1- 50 50.1 or more

SPECIFICATION/TEST THAT JUSTIFIES ABOVE ESTIMATIONS (e.g. NFPA 2001, NFPA 10, etc.)____

SPECIAL DISPOSAL COSTS OR ISSUES____________________________
POWER REQUIREMENTS (if electrical)____________________________

EXTINGUISHER CONTAINER

TOTAL FILLED BOTTLE WEIGHT __________LB.
TOTAL EXTINGUISHANT WEIGHT _________LB. (e.g. Halon, AFFF, dry powder, etc.)

CONTAINER DIMENSIONS
______inches x ______ inches x ______ inches (rectangular volume enclosing system)

CONTAINER MATERIALS: ____________________ OPTIONS: __________________
(e.g. 7076 aluminum, ____________________ __________________
stainless steel, etc.) ____________________ __________________

CONTAINER FILL PRESSURE (at 70 F) __________ psia
Maximum Operational Container Pressure Extreme __________ psia
Maximum/Minimum Operational System Temperature Extreme ____/____ F(ready to operate)
Maximum/Minimum System Exposure Temperature Extreme ____/____ F(safe in storage)

SUPERCHARGING PRESSURIZATION GAS YES NO If yes, what type? ______________

MOUNTING TECHNIQUE FOR CONTAINER ________________________________
____

ACTIVATION VALVE
ACTIVATION MEANS: (Check For Standard, "X" for optional)
Manual Plunger Manual Pull Cable Electrical Squeeze Handle
Melting Fusible Link Other Explain ________________________________

VALVE TYPE (Check All That Apply): Pin/Rupture Disk Cammed Pin Squib/Rupture Disk Solenoid Squeeze (Spring Loaded) Other Explain _________________________

VALVE DIMENSIONS:_______ inches x _______ inches x _______ inches

VALVE WEIGHT: _______ lb.

MAXIMUM OPERATIONAL PRESSURE:________ psia

FLOW RATE: ____ Lb./sec; Per Discharge Location L b ____./sec.; Total Discharge

EXTINGUISHANT

Type (Check One): Powder Clean Agent Wet (Water-based) Other Explain ______________

____

Specific Material, Ingredients ____

____

Particle/Droplet Size (Mean Diameter), if powder or mist: ______________ micron
Density of Extinguishant __________ g/cc
Toxicity Limitations In Use (including combustion byproducts): ____________________

____

Electrically Conductive? (Yes or No) ________________
Corrosivity Effects (including combustion byproducts, pH when wet): ________________

____

Standard Used (ASTM, etc.) ____
Other Use and Storage Issues (Freezing, etc.) ______________________________________

____

Design Concentration/Quantities To Achieve Fire Suppression (e.g. 6% by volume, 5 pounds per 1000 cubic feet, 5 pounds per 100 sq. ft. pool fire, etc.- include effect of temperature on rating):

____

Environmental Impact (including restrictions):______________________________________

____

ACCESSORIES/DISTRIBUTION

DISTRIBUTION PLUMBING: Length ___________ (inches)
Diameter __________ O.D./I.D. (inches)
# of outlets ________

NOZZLES: Number __________
Type (Description) ___________________
Spray Angle (Degrees) __________
Flow Rate (per Nozzle) __________ Lb/sec

Conditions of Extinguishant at Discharge Outlet (Check At Least One)
Stream Particles Mist Gas

Length of Remote Cable Release (If Provided)--Check One:
less than one foot l-2 FT 2.1-4 FT 4.1-8 FT 8.1-15 FT 15.1-25 FT 25+ FT

Additional Relevant Tests, Product Approvals (UL, etc.)______________________________

OTHER RELEVANT INFORMATION (attach sheets if necessary)____________________

____

SURVEY

NON-CONVENTIONAL FIRE EXTINGUISHERS

GAS/AEROSOL GENERATORS, TUBULAR STORAGE AND DELIVERY SYSTEMS, AND EXPLOSION SUPPRESSION SYSTEMS

(Please fill out one copy of this survey for each significantly different model)

NAME OF SYSTEM ______________________________

COMPANY NAME ____

CONTACT PERSON/TELEPHONE NUMBER ____

BRIEF DESCRIPTION OF SYSTEM ____

____

____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

BASIC COMPONENTS OF THE STANDARD SYSTEM: ______________________________

____

____

LIST OPTIONS OF SYSTEM: ____

____

____

CURRENT USES OF SYSTEM IN APPLICATIONS ___________________________________

____

INSTALLATION PROCEDURE FOR VEHICLE APPLICATIONS ______________________

____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST (wholesale) LOT SIZE (COST PER EACH)

	1	1000	10,000	100,000	1 ,000,000
STANDARD SYSTEM:		________	________	________	________
VARIATIONS/OPTIONS:					
________	________	________	________	________	
________	________	________	________	________	
________	________	________	________	________	

ESTIMATED MEAN TIME BETWEEN FAILURES OF SYSTEM (Check One) - Assume Functional During Vehicle Operation Periods

Less than 1 year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

MAINTENANCE SCHEDULE (Check One)

Every Year Everyl. l-3 years Every 3.1-5 years Every 5. 1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One)
No Cost $0-$10.00 $lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

SYSTEM DIMENSIONS:
______inches x _____ inches x _____ inches (rectangular volume enclosing system)

SYSTEM STORAGE VOLUME ___________________ cubic inches
SYSTEM STORAGE WEIGHT ___________________ lb.
DISTRIBUTION SYSTEM WEIGHT (assume 10 ft.) - if any _______________ lb.

WHOLESALE REPAIR/REPLACEMENT COST OF PARTS (fill in blank)

PART TYPE	COST
______________________	_____________
______________________	_____________
______________________	_____________
______________________	_____________

TYPES OF FIRES ADDRESSED (Check all relevant)
CLASS A (cellulosic, textile materials) CLASS B (liquid fuels)
CLASS C (electrical equipment) CLASS D (burning metals)

engine compartment fuel tank exterior fuel tank interior
passenger compartment underneath vehicle fuel dripping on hot surface

spraying fuel fire liquid fuel pool fire fuel vapor explosion

ESTIMATED LIFE OF PRODUCT AS INSTALLED(Assumed not activated/recharged-Check)
Less than one year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

NOTE:(exclude detectors and distribution hardware (non-storage) from next two questions)
CUBIC FEET PROTECTED VOLUME PER CUBIC FOOT OF VOLUME OF SYSTEM (e.g. 1 cubic foot extinguisher system protects 1000 cubic foot of space-- 1000 protected cubic feet/extinguisher cubic foot)
100-300 301- 600 601-1000 1001 - 1400 1401 - 3200 3201 - 4000 4001 or more

CUBIC FEET PROTECTED VOLUME PER POUND OF SYSTEM WEIGHT (e.g. 10 lb. total weight system protects 250 cubic feet of space; 250/10 = 25 protected cubic ft./extinguisher lb. weight)
0 - 5 5.1 - 10 10.1 - 17 17.1- 25 25.1 - 35 35.1- 50 50.1 or more

SPECIFICATION/TEST THAT JUSTIFIES ABOVE ESTIMATIONS (e.g. NFPA 2001, NFPA 10, etc.)____

SPECIAL DISPOSAL COSTS OR ISSUES ____

____

POWER REQUIREMENTS (if electrical) ____

CONTAINER MATERIALS: __________________ OPTIONS: ______________________
(e.g. 7076 aluminum, __________________ ______________________
stainless steel, etc.) __________________ ______________________

CONTAINER FILL PRESSURE (at 70 F) __________ psia
Maximum Operational Container Pressure Extreme __________ psia
Maximum/Minimum Operational System Temperature Extreme ____/____ F(ready to operate)
Maximum/Minimum System Exposure Temperature Extreme ____/____ F(safe in storage)

SUPERCHARGING PRESSURIZATION GAS YES NO If yes, what type? ________________

ACTIVATION MEANS: (Check all that apply)
Electrical/Detector Squib Fired Detonation/Pyrotechnic Cord Heat/Melting Fusible Link
Other - Explain ____

FLOW RATE: ____ Lb./sec; Per Discharge Location Lb./sec; ____ sec. Total Discharge

EXTINGUISHANT USED (Check One): Powder Clean Agent Wet (Water-based)
Other Explain ____

Specific Material, Ingredients ____

Particle/Droplet Size (Mean Diameter), if powder or mist: ______________ micron

Density of Extinguishant __________ g/cc @ 70F

Electrically Conductive? (Yes or No)

Toxicity Limitations In Use (including combustion byproducts): ____________________

____

Corrosivity Effects (including combustion byproducts, pH when wet): __________________

____

Standard Used (ASTM, etc.) ____

____

Other Use and Storage Issues (Freezing, etc.) __________________________________

____

Design Concentration/Quantities to achieve Fire Suppression (e.g. 6% by volume, 5 pounds per 1000 cubic feet, 5 pounds per 100 sq. ft. pool fire, etc. - include effect of temperature on rating): ______________________________

Environmental Impact (including restrictions): ______________________________
____

DISCHARGE CONFIGURATION: Nozzles Container Orifices Other - Explain ______________________________
____

DISTRIBUTION PLUMBING (if any): Length ____________ (inches)
Describe ______________________ Diameter ____________ O.D./I.D. (inches)
______________________ # of outlets __________

NOZZLES(if any): Number _____
Type (Description) ____________________
Spray Angle (Degrees) ____________
Flow Rate (per Nozzle) ____________ Lb/sec

Conditions of Extinguishant at Discharge Outlet (Check At Least One)
Stream Particles Mist Gas If more than one, explain ______________________________
____

Additional Relevant Tests, Product Approvals (UL, etc.) ______________________________

OTHER RELEVANT INFORMATION (attach sheets if necessary) ______________________________
____
____

SURVEY

FIRE DETECTORS

(Please fill out one copy of this survey for each significantly different model)

NAME OF SYSTEM________________________________

COMPANY NAME____

CONTACT PERSON/TELEPHONE NUMBER____

BRIEF DESCRIPTION OF SYSTEM____
____
____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

LIST BASIC COMPONENTS OF STANDARD SYSTEM:_______________________________
____

LIST OPTIONAL COMPONENTS OF STANDARD SYSTEM___________________________
____

CURRENT USES OF SYSTEM IN APPLICATIONS_____________________________________
____

INSTALLATION PROCEDURE____
____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST (wholesale) LOT SIZE (COST PER EACH)

	1 1000	10,000	100,000	1 ,000,000
STANDARD SYSTEM:	________	________	________	________
VARIATIONS/OPTIONS:				
________________	________________	________	________	________
________________	________________	________	________	________
________________	________________	________	________	________

ESTIMATED MEAN TIME BETWEEN FAILURES OF SYSTEM (Check One) - Not Due to False Alarms - Assume Functional During Vehicle Operation Periods

Less than 1 year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

MAINTENANCE SCHEDULE (Check One)

Every Year Every 1.1-3 years Every 3.1-5 years Every 5.1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One)

No Cost $0-$10.00 $lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

DIMENSIONS OF STANDARD UNIT:
______inches x _____ inches x _____ inches (rectangular volume enclosing system)

WEIGHT OF INDIVIDUAL DETECTOR UNIT:______ lb.

COST OF REPLACEMENT DETECTOR UNITS (for those used with centralized processor):
____

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)
Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

POWER REQUIREMENTS: ______ Volts _______ Amps
DC AC OTHER-Explain____

TYPE OF DETECTOR (Check all applicable): Fire Smoke Overheat

TECHNIQUE FOR DETECTING (Check All That Apply): Optical Machine Vision
Pneumatic Thermistor Fiber Optic Thermocouple Ionization Other - Explain
____

DESCRIPTION OF ACTIVATION MEANS, REQUIRED STIMULUS AND OPERATIONAL STEPS UNTIL A CONFIRMED SIGNAL IS OUTPUT TO AN EXTERIOR (SOURCE) RESPONSE UNIT:____
____
____

FALSE ALARM SOURCES:____
____

FALSE ALARM IMMUNITY FEATURES:____
____

ENVIRONMENTAL EXPOSURE TEMPERATURE LIMITS OF SYSTEM _____ F t__o F
OPERATIONAL TEMPERATURE LIMITS OF SYSTEM F to ______ F

DETECTION SENSITIVITY:
Minimum Required Optical Signature Strength__________
Minimum Required Heat Energy Flux __________ Watts/square foot
Minimum Required Temperature Threshold __________ F

SHOCK/IMPACT RESISTANCE SPECIFICATIONS (for considerations of survivability and operability of unit after a vehicle collision, and ruggedness during normal use________________
____

VULNERABILITY TO DIRT/MUD/SALT/GRIME - Explain______________________________

____

OPTICAL DETECTORS ONLY

MAXIMUM DETECTABLE VIEWING VOLUME PER UNIT: __________ (Cubic Feet)
Conical Angle (steradians) (Assume Conical Space In Field of View)

WAVELENGTHS OF DETECTION (check all that apply): UV (ultraviolet) IR (infrared)
Visible

LIST WAVELENGTH BANDS OF DETECTION (list all): ______________________ microns

FIELD OF VIEW (maximum): __________ degrees; ____________ feet

CAPABILITY TO DETECT OTHER THAN DIRECT LINE-OF-SIGHT - Quantify capability

____

RESPONSE TIME CRITERIA (list several criteria):
______________ fire size - ________ seconds detection time at 5 foot distance
______________ fire size - ________ seconds detection time at 5 foot distance
______________ fire size - ________ seconds detection time at 5 foot distance
______________ fire size - ________ seconds detection time at 5 foot distance
______________ fire size - ________ seconds detection time at 5 foot distance
______________ fire size - ________ seconds detection time at 5 foot distance

Additional Relevant Tests, Product Approvals (UL, etc.)__________________________

____

OTHER RELEVANT INFORMATION (attach sheets if necessary)_________________________

____

____

SURVEY

FUEL SHUTOFF DEVICES

(Please fill out one copy of this survey for each significantly different model)

NAME OF DEVICE________________________

COMPANY NAME____

CONTACT PERSON/TELEPHONE NUMBER______________________________________

BRIEF DESCRIPTION OF DEVICE:____

____

____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

LIST BASIC COMPONENTS OF STANDARD DEVICE:______________________________

____

____

CURRENT USES OF DEVICE IN APPLICATIONS______________________________________

____

____

INSTALLATION PROCEDURE____

____

____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST (wholesale) LOT SIZE (COST PER EACH)

	1 1000	10,000	100,000	1 ,000,000
STANDARD DEVICE:	______	______	______	______
ALTERNATIVE DEVICES:				
______	______	______	______	______
______	______	______	______	______

ESTIMATED MEAN TIME BETWEEN FAILURES OF SYSTEM (Check One) - Assume Functional During Vehicle Operation Periods

Less than 1 year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

MAINTENANCE SCHEDULE (Check One)

Every Year Every 1.1-3 years Every 3.1-5 years Every 5. 1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One) No Cost $0-$10.00

$lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

DEVICE DIMENSIONS:
______inches x ______inches x _____ inches (rectangular volume enclosing system)

DEVICE WEIGHT ____________________ lb.

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)
Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

POWER REQUIREMENTS (if electrical) _______ volts ________ amps
DC AC Other - Explain____

ACTIVATION MEANS:____
____

FUELS COMPATIBLE WITH DEVICE (list all major fuels):_____________________________
____

RESPONSE TIME: __________ seconds

ADDITIONAL RELEVANT TESTS, PRODUCT APPROVALS (UL, etc.)___________________
____

ALLOWABLE TEMPERATURE RANGE FOR PROPER OPERATION (activated) ____/____ F
ALLOWABLE TEMPERATURE RANGE IN STORAGE OR NOT ACTIVATED ____/____ F

OTHER RELEVANT INFORMATION (attach sheets if necessary)_________________________
____
____

SURVEY
SELF-SEALING FUEL LINE/COMPONENT PRODUCTS
(Please fill out one copy of this survey for each significantly different model)

NAME OF PRODUCT ______________________
COMPANY NAME ____

CONTACT PERSON/TELEPHONE NUMBER ______________________________

BRIEF DESCRIPTION OF PRODUCT ________________________________
____
____
(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

CURRENT USES OF PRODUCT IN APPLICATIONS _______________________
____
____

INSTALLATION PROCEDURE _____________________________________
____
____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST (wholesale) LOT SIZE (1 lb. increments)

	1 1000	10,000	100,000	1 ,000,000
STANDARD PRODUCT:	________	________	________	________
VARIATIONS/OPTIONS (if any):				
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________

MAINTENANCE SCHEDULE (Check One)
Every Year Every 1.1-3 years Every 3.1-5 years Every 5. 1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One)
No Cost $0-$10.00 $lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

REPAIR COSTS (Assuming Patching/Splicing of Small Damage Area)
0- $10.00 10.01 - $25.00 25.01 - $50.00 50.01 - $100.00 OVER $100.00

ESTIMATED LIFE OF PRODUCT INSTALLED (Assumed not activated or recharged--Check)
Less than one year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

SEALANT MATERIALS:____
____

MAXIMUM/MINIMUM PRODUCT TEMPERATURE EXPOSURE EXTREMES (safe in storage) _____/_____ F

MAXIMUM/MINIMUM PRODUCT TEMPERATURE OPERATIONAL EXTREMES (ready to operate) ___/___ F

TIME TO FILL/SEAL DAMAGE HOLE (CITE PRODUCT SPECIFICATION)______________
____

EXPOSURE LIMITATIONS OF SEALANT TO OTHER MATERIALS, OR TO HUMANS, INCLUDING TOXICITY (if any):____
____
____

PRODUCT APPLICATION WEIGHT (per inch length and inch diameter of fuel line)__________
____

PRODUCT APPLICATION WEIGHT (per square foot of component surface area)____________
____

LARGEST AREA (tube I.D.) THAT CAN BE EFFECTIVELY SEALED WITH PRODUCT IN NORMAL USE____

MAXIMUM FLUID PRESSURE THAT CAN BE RESTRAINED WITH SEALED HOLE_____
____

ADDITIONAL RELEVANT TESTS, PRODUCT APPROVALS (UL, etc.)____________________
____

OTHER RELEVANT INFORMATION (attach sheets if necessary)_______________________
____
____

SURVEY

POWDER PANELS

(Please fill out one copy of this survey for each significantly different model)

COMPANY NAME______________________________

CONTACT PERSON/TELEPHONE NUMBER______________________________

BRIEF DESCRIPTION OF DEVICE:______________________________
____
____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

LIST BASIC COMPONENTS OF DEVICE:______________________________
____
____

LIST OPTIONAL FEATURES OF DEVICE:______________________________
____
____

CURRENT USES OF DEVICE IN APPLICATIONS:______________________________
____
____

INSTALLATION PROCEDURE______________________________
____
____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL DEVICE COST (wholesale) PER SQUARE FOOT (NUMBER ACQUIRED)

	1 1000	10,000	100,000	1 ,000,000
STANDARD DEVICE:	________	________	________	________
VARIATIONS/ENHANCEMENTS TO DEVICE:				
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)

Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

CUBIC FEET PROTECTED VOLUME PER POUND WEIGHT OF DEVICE (e.g. 1 lb. powder panel protects 100 cubic foot space-- 100 protected cubic feet/lb. panel weight)________________

CUBIC FEET PROTECTED VOLUME PER SQUARE FOOT OF DEVICE (e.g. 1 square foot panel protects 50 cubic feet of space; 50/1 = 50 protected cubic ft./panel square foot)___________

PANEL WEIGHT (LB.) PER SQUARE FOOT______________________________
SPECIFICATION/TEST THAT JUSTIFIES ABOVE ESTIMATIONS______________________
____

PANEL THICKNESS RANGES (INCHES)___________________________________

PANEL MATERIALS: ____________________ OPTIONS: ____________________
(e.g. 7076 aluminum, ____________________ ____________________
stainless steel, etc.) ____________________ ____________________
SANDWICH MATERIALS: ____________________ OPTIONS: ____________________
______
(e.g. aluminum, nylon, etc.) ____________________ ____________________
____________________ ____________________

Maximum/Minimum Operational Device Temperature Extremes ____/____ F
Maximum/Minimum Device Exposure Temperature Extremes ____/____ F

SUPERCHARGING PRESSURIZATION GAS: YES NO If yes, what type? ____________

ACTIVATION MEANS:____
____

EXTINGUISHANT USED (Check One): Powder Clean Agent Wet (Water-based)
Other Explain ____

Specific Material, Ingredients_______________________________________
____
Particle Size (Mean Diameter): ______________ micron
Desiccant Used? YES NO If yes, what type?____________________________
Toxicity Limitations In Use:____
____
Electrically Conductive? (Yes or No)____________
Corrosivity Effects (e.g., pH of product in water):_________________________
____
Standard Used (ASTM, etc.)____

MECHANICAL DURABILITY/DAMAGE RESISTANCE (include specification if possible)____
____

ADDITIONAL RELEVANT TESTS, PRODUCT APPROVALS (UL, etc.)________________
____

OTHER RELEVANT INFORMATION (attach sheets if necessary)____________________
____

SURVEY

FLAME ARRESTORS AND RETICULATED FOAMS

(Please fill out one copy of this survey for each significantly different model)

NAME OF DEVICE:______________________________

COMPANY NAME .____

CONTACT PERSON/TELEPHONE NUMBER______________________________________

BRIEF DESCRIPTION OF DEVICE:____

____

____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

CURRENT USES OF DEVICE IN APPLICATIONS:__________________________________

____

____

INSTALLATION PROCEDURE:____

____

____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST: WHOLESALE COST PER POUND MASS OF PRODUCT (LOT SIZE IN POUNDS)

	1 1000	10,000	100,000	1 ,000,000
PRODUCT COST:	____________	________	________	____________

MAINTENANCE SCHEDULE (Check One)

Every Year Every 1.1-3 years Every 3.1-5 years Every 5.1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One)

No Cost $0-$10.00 $lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)

Less than one year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

CUBIC FEET PROTECTED VOLUME PER COMPRESSED CUBIC FOOT VOLUME OF DEVICE (e.g. 1 cubic foot compressed foam or other material expands to protect 33 cubic ft. space-33 protected cubic feet/compressed device cubic foot (only takes up 3 percent of volume))

0 - 10 10.1 - 12 12.1 - 15 15.1 - 20 20.1 - 30 30.1 -45 45 or more

CUBIC FEET PROTECTED VOLUME PER POUND OF DEVICE WEIGHT (e.g. 1 lb. total weight device protects 50 cubic feet of space; 50/1 = 50 protected cubic ft./device lb. weight)
0- 5 5.1 - 10 10.1 -20 20.1-35 35.1 -50 50.1- 80 80.1 or more

SPECIFICATION/TEST THAT JUSTIFIES ABOVE ESTIMATIONS ____________________

DEVICE WEIGHT (POUNDS) PER COMPRESSED CUBIC FOOT VOLUME: __________
DEVICE WEIGHT (POUNDS) PER EXPANDED CUBIC FOOT VOLUME: __________

SPECIAL DISPOSAL COSTS OR ISSUES ____________________

DEVICE MATERIAL: ________________ OPTIONS: ________________

MAXIMUM/MINIMUM DEVICE EXPOSURE TEMPERATURE EXTREMES: ____ / ____ F

MELTING POINT OF DEVICE: F

COMBUSTIBLE WHEN IMPINGED BY FLAME? YES NO

SELF-EXTINGUISHES IF IGNITED? YES NO

ELECTRICALLY CONDUCTIVE (NO STATIC)? YES NO

DETERIORATE IF EXPOSED TO FUEL/OIL/ANTI-FREEZE FOR EXTENDED PERIODS?
YES NO

ADDITIONAL RELEVANT TESTS, PRODUCT APPROVALS (UL, etc.) ________________

OTHER RELEVANT INFORMATION (attach sheets if necessary) ________________

SURVEY

NON- OR LESS FLAMMABLE FLUIDS OR FLAMMABILITY REDUCING ADDITIVES

(Please fill out one copy of this survey for each significantly different type)

NAME OF FLUID____________________________

NAME OF COMPANY____

CONTACT PERSON/TELEPHONE NUMBER____

BRIEF DESCRIPTION OF FLUID:____
____
____

(Please attach brochures or photographs of the product to the back of the survey (with explanation of the items, if necessary)).

LIST BASIC INGREDIENTS OF FLUID:____
____
____

CURRENT USES OF FLUID IN APPLICATIONS_______________________________________
____
____

TOTAL COST(wholesale): LOT SIZE ORDERED (COST PER GALLON)

	1 1000	10,000	100,000	1,000,000
FLUID COST:	________	________	________	________

REPLACEMENT SCHEDULE (Check One)

Every Year Every 1.1-3 years Every 3.1-5 years Every 5.1- 10 years No maintenance

REPLACEMENT SCHEDULE (miles) ___________ miles

FLUID WEIGHT PER GALLON lb.

SUITABLE AUTOMOTIVE SYSTEM APPLICATION - Meeting SAE Specifications (Check one or more):

Oil Brake Fluid Power Steering Fluid Transmission Fluid Other_________________

TYPES OF FIRES PREVENTED (Check all relevant)

spraying liquid fire liquid pool fire vapor explosion ignition from fluid dripping on hot surface

ESTIMATED SHELF LIFE OF PRODUCT (Check One)

Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

SPECIFICATION/TEST THAT JUSTIFIES ABOVE ESTIMATIONS (e.g. ASTM, SAE, etc.)

____

SPECIAL DISPOSAL COSTS OR ISSUES (including environmental restrictions)____________

____

BIODEGRADABLE? (circle one) YES / NO

MAXIMUM/MINIMUM OPERATIONAL TEMPERATURE EXTREMES ____/____ F

FLASH POINT _______ F

EFFECTIVE HEAT OF GASIFICATION AT 70F______________

IS GAS GENERATED IN OPERATIONAL USE IN SYSTEM? (circle one) YES / NO

FLAMMABILITY LIMITS OF VAPOR ___ PERCENT @ ___ F TO ___ PERCENT @ ___ F

DENSITY (ATF) AS A FUNCTION OF TEMPERATURE (-40F to 540F)__________________

VISCOSITY AS A FUNCTION OF TEMPERATURE (-40F to 540F)______________________

COMMON IMPURITIES AND LEVELS OF IMPURITIES:_____________________________

____

ACID/BASE BUFFERING (oils)____

TOXICITY/HUMAN EXPOSURE LIMITATIONS:___________________________________

____

CORROSIVITY:____

____

COMPATIBILITY WITH SEALING AND OTHER MATERIALS:________________________

____

____

STANDARDS, TESTS and PRODUCT APPROVALS USED FOR ABOVE DATA (ASTM, etc.)____

OTHER RELEVANT INFORMATION (attach sheets if necessary)_________________________

____

____

SURVEY

INTUMESCENT/ABLATIVE COATINGS/EXHAUST WRAPS

(Please fill out one copy of this survey for each significantly different model)

NAME OF PRODUCT:______________________________

COMPANY NAME____

CONTACT PERSON/TELEPHONE NUMBER____

BRIEF DESCRIPTION OF PRODUCT AND OPERATIONAL CONCEPT:__________________

____

____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

LIST BASIC COMPONENTS OF THE PRODUCT:______________________________________

____

____

CURRENT USES OF PRODUCT IN APPLICATIONS:__________________________________

____

____

INSTALLATION PROCEDURE:____

____

____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

PRIMER RECOMMENDED? YES NO Explain

SEALANT OR TOP COAT RECOMMENDED? YES NO Explain______________________

____

OTHER SURFACE PREPARATION REQUIREMENTS____________________________________

____

COST (wholesale) Square feet acquired (exhaust wraps) or gallons acquired (coatings/paints)

	1	1000	10,000	100,000	1,000,000
COST PER LOT SIZE:		________	________	________	________

MAINTENANCE SCHEDULE (Check One)

Every Year Every 1.1-3 years Every 3.1-5 years Every 5.1-10 years No maintenance

PRODUCT WEIGHT PER CUBIC FOOT VOLUME: lb/cubic foot

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)
Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

TOXICITY LIMITATIONS IN USE: (including combustion byproducts):____________________
____

CORROSIVITY EFFECTS: (on application area and surrounding area - including combustion byproducts): ____
____

STANDARD USED FOR ABOVE EVALUATIONS(ASTM, etc.):_________________________
____
______

MAXIMUM FLAME TEMPERATURE IMPINGEMENT LIMIT: _____ F
MAXIMUM HEAT FLUX IMPINGEMENT LIMIT: ______ Watts/Square inch

Thermal Conductivity of Intumescent/Ablative Material After Application of Flame (W/m-C)
_____ At 70 F _____ At 300 F

Weathering Tests____

Maximum Storage Temperature Before Material Intumesces______ (C or F)

Intumescent Material Final Thickness per 0.1 Inch of Initial Thickness________ in.

Mechanical and Weathering Durability in an Automobile Underside Application______________
____

ADDITIONAL RELEVANT PRODUCT APPROVALS (e.g. UL 94, ASTM E84-87, ASTM E152, IS0 3008)____
____

OTHER RELEVANT INFORMATION (attach sheets if necessary)_________________________
____
____

SURVEY
FIRE RESISTANT PLASTICS, FABRICS
(Please fill out one copy of this survey for each significantly different model)

NAME OF PRODUCT: ______________________________

COMPANY NAME ______________________________

CONTACT PERSON/TELEPHONE NUMBER ______________________________

BRIEF DESCRIPTION OF PRODUCT: ______________________________

____

____

(Please attach brochures, diagrams and photographs of the product to the back of the survey (with explanation of the items, if necessary)).

LIST BASIC COMPONENTS OF THE PRODUCT: ______________________________

____

CURRENT USES OF PRODUCT IN APPLICATIONS: ______________________________

____

COST (wholesale) Square feet acquired (fabrics) or gallons acquired (plastics)

	1	1000	10,000	100,000	1,000,000
COST PER LOT SIZE:	______	______	______	______	

PLASTICS: Density: _____ lb/cubic foot
FABRICS: Weight per unit area: ______ oz/sq. yard

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)
Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

TOXICITY LIMITATIONS IN USE: (including combustion byproducts): ______________________________

____

STANDARD USED FOR ABOVE EVALUATION(ASTM, etc.): ______________________________

____

IGNITION TEMPERATURE: _________ F (IS0 5660)

HEAT RELEASE RATE IF EXPOSED TO 10 KW/sq. in. 20 KW/sq. in.
30 KW/sq. in. _________

OVERALL PERFORMANCE (TEST NAME AND RESULTS - e.g. Cone Calorimeter, LOI) ___

____

TEST RESULTS FROM ISO-5660 ______________________________

TEST RESULTS FROM MVSS 302 OR OTHER FLAME SPREAD TEST ____________________

____

SUGGESTED AUTOMOTIVE COMPONENT APPLICATIONS: ____________________

____

FOR PLASTICS - USED AS OR WITH FOLLOWING PLASTIC TYPES IN IMPROVING FIRE RESISTANCE:
polyethylene polypropylene Other ____________________

____

RELEVANT TESTS AND PRODUCT APPROVALS (e.g. UL 746C, ASTM D-790) ____________________

____

OTHER RELEVANT INFORMATION (attach sheets if necessary) ____________________

____

____

SURVEY

OTHER TECHNOLOGIES

(Please fill out one copy of this survey for each significantly different model)

NAME OF PRODUCT:____________________________

COMPANY NAME____

CONTACT PERSON/TELEPHONE NUMBER______________________________________

BASIC DESCRIPTION OF PRODUCT:____

____

____

(Please attach brochures, photographs, diagrams, or drawings of the product to the back of the survey (with explanation of the items, if necessary)).

BASIC COMPONENTS OF THE STANDARD PRODUCT:_____________________________

____

____

VARIATIONS/OPTIONS OF PRODUCT:____

____

CURRENT USES OF PRODUCT IN APPLICATIONS:_____________________________

____

INSTALLATION PROCEDURE:____

____

INSTALLATION TIME 15 MIN 30 MIN 1 HOUR 2-4 HOURS

TOTAL SYSTEM COST- LOT SIZE ACQUIRED(COST PER EACH UNIT (specify_______))

(wholesale)	1 1000	10,000	100,000	1 ,000,000
STANDARD PRODUCT:	________	________	________	________
VARIATIONS/OPTIONS:				
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________

ESTIMATED MEAN TIME BETWEEN FAILURES OF PRODUCT: (Check One) - Assume At Least Functional During Vehicle Operation Periods

Less than 1 year l-3 years 3.1-5 years 5.1-10 years 10.1-20 years 20+ years

MAINTENANCE SCHEDULE (Check One)

Every Year Every 1.1-3 years Every 3.1-5 years Every 5.1- 10 years No maintenance

AVERAGE ANNUAL MAINTENANCE COST (Check One)

No Cost $0-$10.00 $lO.Ol-$25.00 $25.01-$50.00 $50.01-$100.00 Over $100.00

PRODUCT DIMENSIONS (if appropriate)
______inches x _____ inches x _____ inches (rectangular volume enclosing system)

PRODUCT VOLUME (if appropriate)_______ cubic inches
PRODUCT WEIGHT (if appropriate) _______ lb.

COST OF REPLACEMENT PARTS____
____

TYPES OF FIRES ADDRESSED (Check all relevant)
CLASS A (cellulosic, textile materials) CLASS B (liquid fuels)
CLASS C (electrical equipment) CLASS D (burning metals)

engine compartment fuel tank exterior fuel tank interior
passenger compartment underneath vehicle

spraying fuel fire liquid fuel pool fire fuel vapor explosion fluid dripping on hot surface

ESTIMATED LIFE OF PRODUCT INSTALLED (Check One)
Less than one year l-3 years 3.1-5 years 5.1- 10 years 10.1-20 years 20+ years

COST OF PRODUCT PER LEVEL OF PROTECTION (e.g. cubic or/square foot of protected space, particular temperature thresholds, etc.)____
____

WEIGHT OF PRODUCT PER LEVEL OF PROTECTION (e.g. cubic or/square foot of protected space, particular temperature thresholds, etc.)________________________________
____

OTHER LIMITS OF PERFORMANCE (at range of temperatures in use)____________________
____

SPECIFICATION/TEST THAT JUSTIFIES ABOVE ESTIMATIONS (e.g. NFPA 2001, NFPA 10, etc.)____

SPECIAL DISPOSAL COSTS OR ISSUES____
____

POWER REQUIREMENTS (if electrical)____

PRODUCT MATERIALS:	______________________	OPTIONS:________________________
(e.g. 7076 aluminum,	______________________	OPTIONS:________________________
stainless steel, etc.)	______________________	OPTIONS:________________________

MAXIMUM/MINIMUM OPERATIONAL PRODUCT TEMPERATURE EXTREMES ___/___ F
MAXIMUM/MINIMUM PRODUCT EXPOSURE TEMPERATURE EXTREMES ___/___ F

ACTIVATION MEANS: ____

____

EXTINGUIS HANT DETAILS (if appropriate) _______________________

____

TOXICITY LIMITATIONS IN USE (including combustion byproducts): ____________

____

CORROSIVITY EFFECTS (including combustion byproducts): ______________

____

STANDARDS USED (ASTM, etc.): __________________________________

OTHER USE ISSUES (Freezing, etc.) ______________________________

____

ENVIRONMENTAL IMPACT (including restrictions): ___________________

____

RELEVANT TESTS AND PRODUCT APPROVALS ________________________

____

OTHER RELEVANT INFORMATION (attach sheets if necessary) ____________

____

____

APPENDIX B: DESCRIPTION OF SURVEY ITEMS

1. Conventional Fire Extinguishers

A. Definition - This classification included those active extinguishing systems that feature a commonly used pressurized container (generally spherical or cylindrical) that houses various types of fire extinguishants that are discharged. They are discharged either directly from an attached valve or through plumbing, when activated either manually by a plunger or pull handle, or automatically via use of a frangible heat sensitive bulb or heat/fire detector.

B. Name of System/Company Name/Contact Person/Telephone Number - This generic information was requested on each survey type to assure that the product disclosed was well defined and understood by the later evaluators. A focal point, which could be reached for clarification, was established for each product.

C. Brief Description of System - This category was also used in each survey to give the opportunity for the manufacture to describe the overall system. It ensured that the reviewers did not have mistaken presumptions or confusion regarding the product, and described any other product features not addressed in the survey. Other supporting material was also requested.

D. Basic Components of Standard System - A checklist of potential components of the particular product type was listed, such as type of container, valve, nozzles, etc. Another checklist for variations and options of the system was also requested.

E. Current Uses of System in Applications - Self-explanatory.

F. Installation Procedure for Vehicle, Installation Time - Self-explanatory. Devices that require an extended time period for installation will translate into large costs in an automotive mass production environment.

G. Total System Cost - The wholesale cost to a major distributor was requested. The retail cost to the public is much too premature at this time, and retail costs for markets in which the products are now used typically are much smaller than the automotive market. This cost was requested per lot size in orders of magnitude, to determine if economies of scale could be realized. This cost was also requested for variations and options of the system. The cost for component replacement parts was also requested.

H. Estimated Mean Time Between Failures of System – This information was requested to establish reliability criteria and associated costs.

I. Maintenance Schedule and Average Maintenance Cost – This data was requested to establish maintenance cost criteria.

J. System Dimensions, Storage Volume and Weight - This data establishes the space requirements necessary for the device to accommodate its storage on an equipment-packed vehicle. This data includes the overall exterior dimensions required when key dimensions are critical, as well as the weight that is needed to assess its resultant impact on vehicle performance and fuel economy).

K. Types of Fires Addressed - The formal industry classification of fire types (Class A/B/C, which the products are typically approved for), as well as different locations and types of fires on a vehicle, were all listed with a checklist provided. This assisted in the product evaluators'understanding of the capabilities of the system in question, as well as the types for which it has been forrnally approved. These determinations of applicability were reassessed by the evaluators.

L. Estimated Life of Product as Installed - This category is of fundamental importance for automobiles, which have lengthy warranties and are expected to be in use for many years after the warranty period. In addition, safety equipment is particularly sensitive to concerns regarding its lack of reliable use when initiated as vehicles age in use. It is not uncommon for many active fire protection systems to be replaced after five years in many vehicle applications under current procedures. This'is due to the lack of and unlikely potential for the institution of an acceptable, widespread inspection process to detect leakage, corrosion and mechanical damage. The exposure scenarios of the systems over their life of the vehicle and the resultant mechanical shocks, vibration and thermal cycling are also unknown.

M. Cubic Feet Protected per Cubic Foot Volume of System, Pound of System Weight - This expression was an attempt to assess the breadth of protection and range provided for a given unit volume and weight of a system. Manufacturers do not usually express the performance of their products in this manner (except for weight and space critical applications such as aviation and marine). This configuration, however, would allow the evaluators to compare the weight and space impacts of products that are very diverse in terms of their features and means of activation (including those from the other survey types). Any recognized standard or specification that was used to justify the calculation was also requested.

N. Disposal Costs, Issues - This information is pertinent for products that may contain substances that are recycled or potentially hazardous materials environmentally in which their disposal is controlled by regulation. This issue and its cost must be accounted for in the impact analysis. ,

0. Power Requirements: - This requirement not only impacts the need of providing power potentially from the vehicle electrical supply, but may limit the survivability of the product to function given an interrupted power supply during or after a crash.

P. Container Specifications - Independent data were collected for the extinguishant container in terms of weight, space, dimensions, materials, fill pressure and mounting techniques. This allows a more understandable analysis of the features and weight and space impacts of different extinguishing systems comparably. This is needed since the global system data may mask some unique, advantageous (or disadvantageous) features of the key components of a given system. The space advantages of a small container of a product, for example, may be masked by the space requirements of plumbing, valves and other associated equipment normally provided with the system but unnecessary for passenger vehicle use. This allows a more careful and fair comparison of the systems and may suggest optimal designs that feature the best aspects of all the similar systems. Specifications such as the fill pressure are important, since the features of the high pressure containers may affect their survivability in a crash or the potential for injury to an individual near a discharged and/or detached unit, either due to a crash or maintenance actions.

Q. Activation Valve - Similar data were requested for the activation valve, a key part of any conventional fire extinguishing system. Specification of the particular type of valve and activation means, as well as flow rate, was requested. The activation means will affect the variety of possible initiation scenarios in a crash.

R. Extinguishant Type/Specification: This section of inquiry is crucial to the analysis of an extinguishing system. The choice of extinguishant and manner of dispersal dictates its primary effectiveness in the vehicle environment. Beyond the specification of the type of extinguishant, the size of the particle or droplet (if applicable), liquid density of the extinguishant, toxicity, corrosivity and conductivity effects, environmental impact, design concentrations (or other relevant measure of effectiveness), and the recognized standards used to establish these criteria were requested.

S. Accessories/Distribution System - Relevant specifications about the accessories and distribution system, such as the system length and tubing diameter, nozzle type and flow rate, and features of the remote activation system were requested. This data provides information on the requirements for successful use of the device. These include space requirements to route plumbing of given diameters to the capability to protect multiple locations with multiple orifices and nozzles, and the capability to "total flood" cluttered compartments based upon the physical state of the extinguishant upon discharge.

T. Other Relevant Tests, Product Approvals - Data on other recognized tests, in-house experiments or product approvals by outside agencies that have acknowledged a certain level of performance of the product independent of those mentioned in the survey were requested.

U. Other Relevant Information -- Additional information not requested in the survey but deemed pertinent to the completion of the project is requested.

2. Non-Conventional Fire Extinguishers

A. Definition - Non-conventional fire extinguishers include those systems which generate and/or discharge their extinguishant by some unconventional means. This includes solid propellant gas generators and pyrotechnic aerosols, which instantaneously create their extinguishants when initiated due to a pyrotechnic chemical reaction that occurs internally, liberating copious quantities of inert gases or particulate extinguishants. The newly explored flexible plastic tubular fire extinguisher system also belongs in this category. This is because its discharge mechanism functions via the weakening and rupture of the tubing itself when heated to release the stored extinguishant to the seat of the fire. Explosion suppression systems are also included in this category, since they frequently use unconventional means to discharge their contents. These means include a pyrotechnic cord instantly pressurizing the internal contents of the device or literally ripping a seam down the length of the container, discharging its contents. All of these devices have characteristics in which their storage containers and packaging may be more efficient on a weight basis than a conventional extinguisher. This is because most are not normally pressurized, and have different design and operational issues in some respects. The most notable examples of design and operational data which were requested and follow in this description are those that distinguish themselves from a conventional system. Most of the "generic" categories of system data which were collected in the survey on "Conventional Fire Extinguishers" apply here. They were included in the survey and will not be mentioned again in this description (The same will be true for the other survey descriptions).

B. Discharge Configuration - A checklist of various discharge means is listed, since these discharge systems vary widely in their operation, from external nozzles and orifices cut right into their containers to the rupturing of the container itself. Special sections on the extinguishant are not included in this survey since they may not have such items, or detailed information in these sections such as storage pressure may not be relevant.

3. Fire Detectors

A. Definition. This category covers those devices that sense the presence of conditions which suggest a fire was initiated or is imminent. This includes actual detection of the fire itself, from detection of the optical ultraviolet/infrared signature unique to a hydrocarbon fire to flame color/shape pattern recognition utilizing machine vision principles. They may also detect the heat generated either by the fire or overheating components that could lead to a fire event, by use of localized thermocouples/thermopiles or linear thermal or pneumatically-activated devices. Hydrocarbon gas detection devices, although they do not detect a fire, are also included in this survey since they can detect a leak of gas fumes that can signal an imminent fire condition. Smoke detectors also qualify under this category, since they detect smoke emanating from an active or smoldering fire, although their delayed response time may not be practical for a fast-growth vehicle fire.

B. Weight of Individual Detector Units - The weight of the individual detector units is important, since a system layout may have multiple detectors in various locations. The number and location of the detectors depends on the desired breadth of coverage and the coverage limitations of a particular detector unit design. The cost of individual replacement detector units is important, since it is likely that one or more may malfunction or be damaged over the course of a vehicle's operational life.

C. Power Requirements **-** The detectors may require AC power, DC power or both, at various power requirements (some well above that which is practical for vehicle use). The possibility also exists for other power sources such as replaceable battery units.

D. Type of Detector, Technique for Detecting and Activation Description **-** These categories assist in classifying the detectors according to their activation signal type and method of detecting the signal (discriminated in a fashion similar to that in the definition above). The description of the activation process is useful in determining what activation time is necessary. Activation time includes: (1) the initial impingement of the signal on the detector, until a significant threshold is reached to trigger the device, (2) any false alarm processing that occurs and/or checking for secondary signal sources, and (3) the type of output from the detector that is directed to the extinguishing unit or the occupant.

E. False Alarm Sources and False Alarm Immunity Features **-** This is a critical aspect in the evaluation of the operational feasibility of a detector in a vehicle application.

F. Temperature Limits of System: Exposure and Operational **-** Some detectors have a narrower band of performance and tolerance to temperature extremes than those encountered during the range of automobile operations and climates. There are typically separate temperature extremes allowable for mere exposure versus being capable to operate fully at a given temperature.

G. Detection Sensitivity: This parameter is important to determine how fast a detector can respond to a fire. The more sensitive the detector, the smaller the fire it detects, and therefore detection occurs earlier in the fire event. This has a direct bearing on the probability of an activated extinguishing system to extinguish a given fire. Without special false alarm immunity, a detector that is too sensitive may produce a greater number of false alarms and possess a propensity for them. A detector with a capability to detect a smaller fire or at a greater distance, , or even a wider field of view, can allow the use of fewer detector units and thus decrease cost and weight. The values requested for this portion of the survey are minimum threshold quantities of initiation for each of the appropriate input signal types that correspond to the particular detector being evaluated. These signature types include optical signature, heat flux or minimum temperature.

H. Shock/Impact Resistance, Vulnerability to Dirt/Mud/Salt/Grime **-** The real world requirements for vehicular use to withstand crash-induced shock and impact are necessities that must be assessed realistically for each detector unit. This also includes the shock sustained during inadvertent bumping during regular vehicle maintenance, and its insensitivity to the covering of the detection head by contaminants such as dirt, mud, salt and grime. Some types of detectors are designed specifically to operate in such dirty environments, and include specifications for their limits of exposure. In addition, the assessment of resistance to corrosion or degradation due to contact with common fluids associated with automobiles, such as brake and transmission fluid, washer fluid or cleaning and de-greasing chemicals, is recommended.

I. Special Issues for Optical Detectors - An additional list of specifications for optical detectors was requested. These included (1) the maximum detectable viewing volume (measured in steradians), (2) the appropriate wavelengths of detection (ultraviolet, infrared or visible), (3) the particular wave bands of detection (in microns), (4) the depth of field of view (in feet), and (5) the capability to "see" signals in other than the direct line-of-sight. These specifications can be compared to the optical spectra and signature of gasoline, oil, transmission fluid, power steering fluid and oil fires to assure that they will be detected. The effective width and depth of view, as well as line-of-sight limitation will determine the required placement of the detectors within the vehicle compartments. A detector with the maximum field and depth of view, broad signal reception spectra (but not too broad so as to be vulnerable to false alarms) and the capability to receive signals outside of the direct line of sight would be superior in performance to detectors lacking these features.

J. Response Time Criteria - No absolute standard exists that is relevant to all applications that compares a detector response time at a given distance from a given size diameter fire. For that reason, a series of relevant fire size and associated response times were requested, at the discretion of the manufacturer, from the data they currently possess. It was assumed that the manufacturers would respond with fire sizes relevant to a vehicle from their own database.

4. Fuel Shutoff Devices

A. Definition – These are typically electromechanical devices located at strategic points of the fluid system. When initiated by the occupant, a system pressure drop, a fire detector or inertially by the crash itself, the device will shut off a supply of fuel (or other fluids). This will discontinue a leak or spray from a damaged section of the plumbing or reservoir. The shutoff is usually accomplished by crimping a line or activating a valve.

B. Fuels Compatible with Device - Some units will only work for certain types of fuels or fluids. The unit may also have limitations on the system pressure or flow rate it can accommodate. A device that is applicable to most or all of the variety of flammable fluids used on a vehicle is desired.

C. Response Time - These devices vary widely in the response time from initiation or damage of the system to the complete shutoff. Such times vary from a few hundredths of a second to several seconds. A device with a faster response time is most desirable to minimize the spillage of fluid.

5. Self-Sealing Fuel Line/Component Products

A. Definition - These products inhibit the supply of fuel from reaching the fire site. When a fluid system component is damaged, an outer jacket around the component contains a viscous sealant, which flows into the damaged region and seals the fracture (if it is not too big), stopping the flow of fluid through it. The weight impact of these devices on the vehicle is based upon the surface area over which the product is applied and the thickness required to seal a given fracture.

B. Sealant Materials - Different types of sealant materials are used for self-sealing fuel line components or products. Natural rubber-based derivatives are the most common type.

C. Maximum and Minimum Exposure and Operational Limits - It is important to note that self-sealing materials can be more susceptible to temperature limits than other products. They must flow like a viscid liquid under a wide range of temperatures, and not harden over time due to their environmental exposure.

D. Time to Fill/Seal Damage Hole - This parameter is critical, as with the response time for the fuel shutoff devices, since the quicker the fuel flow is stopped, the less fuel there is to add to the fire or to come in contact with ignition sources and start a fire. If the fuel released is significant enough and is ignited, the resultant fire may be so intense as to melt the sealant and potentially render it ineffective.

E. Exposure Limitations of Sealant to other Materials or Humans, Including Toxicity - The potential exists for some sealants to react with other materials or on contact with human skin. Some of the products currently available do not appear to pose serious problems, since they are used in similar environments. Documentation of symptoms of toxicity as a result of human exposure to these substances is needed. The toxicity data may screen out unacceptable products or those suitable only for limited use, if such products exist.

F. Product Application Weight (per inch length, diameter, square foot) - Since these products are weight additive per unit area of their application, the weight impact is requested in comparable units. The weight impact for coverage for fluid lines and tubes, however, is usually expressed per unit length of tube and diameter, since the exterior is coated.

G. Largest Area or Tube Diameter that can be Sealed with Product - This parameter determines the maximum constraints on the range of failure conditions that can occur in which this product can be expected to accomplish its task. The maximum damage area that one of these products can address can be used to discriminate the relative performance of different products.

H. Maximum Fluid Pressure That Can Be Restrained - Responses to this parameter also can determine which automotive applications are acceptable for these types of products and which of the products are applicable over the widest range.

6. Powder Panels

A. Definition - Powder panels are unique devices that are usually non-pressurized and contain fire extinguishing dry chemical powders. They are mounted on strategic structural locations near flammable fluid sources, such as on the fuel tank. The thin, hollow, powder-filled panels (sometimes reinforced) are initiated when a crash event ruptures them while simultaneously rupturing a flammable fluid source.

B. Device Cost **-** This is specified per square foot due to the surface application of the device.

C. Cubic Foot Protected Volume Per Pound and Cubic Foot of Device **-** Since a powder panel is a special form of a “fire extinguisher”, the volume of area protected per unit volume and pound of device is relevant. This allows a comparison to other technology types.

D. Panel Weight Per Square Foot **-** This specification establishes a relationship between the weight of panel necessary to provide sufficient protection versus the subsequent square footage required. This is compared to the area required to protect the surfaces of key components.

E. Panel Thickness Ranges **-** These ranges establish the limits of protected volume per square foot and the limitations of placing such panels in tightly constrained areas.

F. Mechanical Durability/Damage Resistance **-** Data on the capability of the panels to resist inadvertent damage due to maintenance actions and even small road debris is requested, if such data exists.

7. Flame Arrestors and Reticulated Foams

A. Definition **-** These devices stop the propagation of the flame without totally blocking the physical path (as opposed to intumescent or ablative coatings, which completely block the physical path of the fire), by the use of a 2-D or 3-D mesh material. This material extracts heat and slows the propagation of a flame front until it can no longer be self sustained and propagating. These materials are typically assessed based upon their weight per unit volume and applied surface area.

B. Cost **-** For these products, cost is typically based per pound of product.

C. Cubic Feet of Protected Volume Per Compressed Cubic Foot Volume of Device **-** When these products are used within an enclosed volume (such as in a fuel tank), they are compressed a given amount when installed (depending upon the product). In this instance, the total maximum compressed volume of the product is intended to relate the compressed density to the resultant volume protected when it is expanded to the desired level.

D. Device Weight per Compressed/Expanded Foot Volume **-** This value will vary greatly between that when it is fully compressed (the limiting case of compression within the tank), and that when it is not forcibly compressed at all (the other limiting extreme case in the tank). In addition, the value will vary when these products are used for other applications to stop the propagation of a fire outside of a totally confined space. This data would allow, on a weight and space basis (adjusted for compression requirements), a comparison of the different flame arrestor/foam products. Other different types of technologies that use different means can also be compared to determine the best choices to protect a given space.

E. Special Disposal Costs or Issues - This issue may be important for the application of this product within the fuel tank, for it can retain significant quantities of fuel when drained and removed (up to 3%), which may be discharged to the ground or atmosphere. In addition, the material does not normally biodegrade, although it may be recyclable. This external exposure might occur with some frequency since fuel tank reticulated foam should be replaced approximately every ten years (at least for aviation applications).

F. Combustible When Impinged by Flame/Self-Extinguishes/Electrically Conductive - Although these products are designed to intercept and stop the progress of a flame front, they may either melt or bum if a sustained ignition source is applied to them. This is not normally a problem within a fuel tank, where this product is typically used to stop and extinguish an instantaneous fast moving flame front that could accelerate into an explosion. Usually, most of these materials will self-extinguish if the ignition source is withdrawn. However, for some exterior fuel tank applications, a scenario may occur where a sustained heat and ignition source is applied to them. In addition, it is desirous that the material be electrically conductive when used in the fuel tank, so that static charge does not build up as the fuel sloshes through it over time and discharge electrical sparks, which can degrade the foam.

G. Deteriorate When Exposed to Fuel/Oil/Anti-Freeze - Foams used in the fuel tank will eventually degrade over time while in contact with fuels. Little is known about their reaction to other fluids, which may be relevant if they are used for some exterior applications (such as filling voided regions in which fuel can spill).

8. Non- or Less Flammable Fluids or Flammability Reducing Additives

A. Definition - These products are fluids that are now used or could be used as substitutes for existing automotive fluids, such as power steering, brake, transmission fluids and oils. Their main feature is their fire resistance under conditions occurring during a vehicular fire event. Additives that are blended into existing automotive fluids could also fall into this category.

B. Cost, Weight Per Gallon - This is an expression for the product cost and weight per application.

C. Replacement Schedule and Shelf Life (years/miles) - The life of these fluids, whether they be dependent upon age or mileage, may vary based upon their composition and additives, which directly affects cost. Such products may also have a limited shelf life before being installed.

D. Suitable Automotive Application and Types of Fires Prevented - Different products may be suitable for one or more fluid applications and mitigate one or more types of fire scenarios involving the fluid. The Society of Automotive Engineers (SAE) specifications for these products were requested.

E. Disposal Costs/Issues/Biodegradability - These fluids may require special handling and disposal procedures. Excessive costs associated with particular products and their disposal issues should be identified and accounted for.

F. Flash Point/Heat of Gasification/Flammability Limits of Vapor - These properties relate to a fluid's overall flammability and potential to ignite under various conditions. They are critical in assessing the value of incorporating these products to reduce the potential of fire or the magnitude of the fire. Even highly fire resistant products can bum under the right conditions; the intent in the collection of this data is to identify products that do not exhibit this tendency over the potential operating conditions and crash scenarios anticipated.

G. Density/Viscosity/Operating Temperature Extremes/Gas Generation/Acid-Base Buffering/Level of Impurities - These characteristics of the fluids evaluated will assist in determining which applications are suitable, if any.

H. Toxicity/Corrosivity/Compatibility with Seals - These products, while functioning ideally for their operational requirements, may be unsuitable due to their effect upon exposure to humans, metals, seals and other materials. The data collected from this section will be used to determine which applications are acceptable for each product with acceptable levels of risk.

9. Intumescent/Ablative Coatings/Exhaust Wraps

A. Definition - These products all stop the progress of a fire in a particular direction by resisting the bum through of the fire through a physical barrier or preventing the contact of flammable substances with hot surfaces. For automotive use, these products are primarily applied onto the exterior of the front and rear bulkheads of the passenger compartment and the floor pan to prevent bum through to the passengers. They may also have strategic applications when applied to key components which, if impinged directly by the fire, may add significantly to the fire load, such as the fuel tank. These coatings may not only stop the progress of the fire but may expand off of the applied surface, dissipating heat and potentially blocking off collateral fire paths. Exhaust wraps may be simple insulative fabric-based strips that are wrapped around hot components, such as the exhaust pipe, to prevent flammable materials or fluids from igniting off of their bare surfaces.

B. Primer/Sealer/Top Coat/Surface Preparation - Many such products, when applied as a coating, require additional surface treatments to provide long life operability. Such treatments, and the labor to apply them, add additional cost.

C. Maximum Flame Temperature/Heat Flux Impingement Limit - For those products that are designed to withstand impingement directly by a flame, these limits suggest which are appropriate for different applications on the automobile. They also suggest which fire scenarios they will address effectively. For example, those products that continue to protect at the highest flame temperatures and heat fluxes may be acceptable for the more challenging applications, such as on the bottom of the floor pan to resist a large pool fire directly underneath it.

D. Thermal Conductivity - This parameter is a direct measure of a product's ability to insulate by determining what types of temperatures can be expected on the other side of the barrier, such as in the passenger compartment.

E. Weathering Tests - This is important to assure that a product will function for a lengthy period, particularly if it is applied to the exterior of the car.

F. Maximum Storage Temperature Before Intumescence - This value will dictate whether the product can be stored under hot conditions without prematurely activating, and at what temperatures it will activate in the event of a vehicle fire.

G. Final Intumescent Thickness Per 0.1 Inch Application - If a product swells a large amount when impinged, it might block off other paths of fire propagation.

H. Mechanical and Weathering Durability in the Underside Application - If applied on the floor pan underneath the vehicle, the coating will be subject to many types of abuse, including road salt, road debris, and gravel. Mechanical and weathering durability data would assist in determining product viability for this application.

I. UL 94, ASTM E84-87, ASTM E152, IS0 3008 - These standardized tests from organizations such as Underwriter's Laboratory and the American Society of Testing and Materials provide information on these types of products and applications. This data would assist in the comparison of test products.

<u>10. Fire Resistant Fabrics, Plastics</u>

A. Definition - These products would potentially replace existing products used on the automobile because they retain the same function yet have improved fire resistance. Applications that would likely accommodate such products are the plastic reservoirs and ducting in the engine compartment and under the dash, insulation under the hood and surrounding electrical components, upholstery and sound deadening material.

B. Density - Different types of products are measured differently. Plastics are measured in ounces per cubic foot for plastic while fabrics are measured in ounces per square yard.

C. Ignition Temperature - All materials, including the fire resistant varieties, will eventually ignite as temperatures increase. This value will assess, whether or not the required ignition temperature will be achieved in an automobile fire, and whether the passengers would be in grave danger due to the resulting heat and thereby be irrelevant.

D. Heat Release - The heat release rate of an ignited material contributes to the fire event. A product may have drastically lower heat release rates, including limiting its reaction to smoldering, and thereby greatly reducing its contribution to the fire event. This will reduce the overall fire threat and potentially prevent the collateral ignition of other materials within its vicinity.

E. Test Results (Cone Calorimeter, LOI, ISO-5660, FMVSS-302, UL 746C, ASTM D-790, etc.) - Standardized fire tests that are relevant to fire resistant materials, such as flame spread tests, can assess in an unbiased fashion their utility for automotive applications. The data allows comparison with other products similarly tested.

F. Plastic Product Substitution or Relevant Additive - For the fire resistant plastic products, it is important to know the plastic types that they can replicate in operational performance. If they are simply additives to such plastics, the breadth of component applications of the product should be determined.

11. Other Technologies

A. Definition - Products that do not fit easily within one of the earlier survey categories are described using this “generic” survey. This survey requests relevant data to allow a product’s comparison to those described in the other surveys, with sufficient content of a generic nature without presupposing any presumptions about the product’s characteristics.

B. Cost or Weight of Product Per Level of Protection - The manufacturer can specify what level of protection is relevant to their product’s cost and weight constraints.

APPENDIX C. RATING LAYOUT AND DESCRIPTION

The protocol used to rate the survey technologies is shown in Table C- 1. Columns one and two (Categories and Subcategories), relate to the capability of a technology to mitigate relevant fire scenarios. Column one (Categories) separates the front and rear fire scenarios respectively. These categories are split into three sub-categories in column two, reflecting the capability to prevent, extinguish or retard fires in the front or rear, with preference in that order and points awarded accordingly. The maximum points in each category were then split between the possible fuel/ignition combinations used in combination with a given fire- mitigating product described in column three (Description). In using this approach, it was assumed that a product should be given credit for either preventing, extinguishing or retarding fires for a given fuel/ignition source combination. The product is awarded points according to the highest point value capability it can demonstrate with priorities for capabilities to prevent, extinguish or retard in preferred order. It is acknowledged that some products might function in more than one subcategory for a given combination according to some interpretations, but it is not desired to award any more points than what was decided to proportionally represent these categories in the rating. However, if a technology prevents some types of fuel/ignition source combinations and extinguishes or retards others, it would be given all of the relevant points, with preference for the highest level of protection for each fuel/ignition source combination. Under any circumstances, the point totals for the front, rear and combination of front and rear categories should never exceed 37.5, 12.5 and 50 points respectively.

The first category assesses the product's capability to address "Front-end and Under-hood Fires". It contains three quarters of the points (37.5) allocated to account for a technology's capability to address particular types of fires. Prevention of ignition is given the full 37.5 points in Sub-Category (1). Partial scores would be given proportional to the number of combinations addressed. Using this approach, the eight suggested scenarios split the 37.5 points, with 4.7 points apiece. For the first flammable material, solids, the possible ignition sources are hot surfaces (such as the exhaust manifold) and electrical (such as hot shorting wires). For gasoline fuel, either hot surfaces, electrical energy or friction sparks can serve as ignition sources. Sparks and heat from friction can originate from grinding metal and components during the crash event. "Other Fluids" can include transmission fluid, brake fluid, oil or power steering fluid. These fluids may be susceptible to the same three ignition sources as gasoline.

For Sub-Category (2), "Suppressing Front End Fires", 30 points were awarded to suppressing fires. These points were split up between initially suppressing, or extinguishing the fire (2a) and preventing re-ignition of the fire (2b). 18 points of the 30 allocated for this sub-category were awarded for initial extinguishment of the fire and 12 points for the prevention of re-ignition. The 18 points were split between extinguishing the three fuel types - solids, gasoline and other fluids. The scenarios were split amongst the fuel types rather than the ignition sources, since ignition is presumed if extinguishment is required. In contrast, subcategory (2b) does pertain to preventing re-ignition, therefore the relevant ignition sources must be differentiated, since some extinguishants are not rated for electrical fires. The 12 points are split evenly between the ignition sources. Friction was not included, since it is presumed that friction is not occurring when the extinguishant is discharged. If a technology both extinguishes certain fires and prevents re-ignition of those types of fires, they receive credit for both capabilities.

TABLE C-1 - FINAL RATING CONFIGURATION

CATEGORY	SUBCATEGORY	DESCRIPTION	POINTS
A. FRONT-END AND UNDER-HOOD FIRES	(1) Prevent Ignition Involving.. .	(a) solids in conjunction with	
		(i) a hot surface	4.7
		(ii) electrical	4.7
		(b) gasoline	
		(i) a hot surface	4.7
		(ii) electrical	4.7
		(iii) friction	4.7
		(c) other fluids	
		(i) a hot surface	4.7
		(ii) electrical	4.7
		(iii) friction	4.7
	(2a) Suppress Fire Involving.. .	(i) solids	6
		(ii) gasoline	6
		(iii) other fluids	6
	(2b) Prevent Re-Ignition Of The Fire Due To.. .	(a) a hot surface	6
		(b) electrical	6
	(3) Retard A Fire Involving.. .	(a) solids	2.5
		(b) gasoline	2.5
		(c) other fluids	2.5
TOTAL			37.5
B . REAR-END GASOLINE-FED FIRES	(1) Prevent The Ignition Of Rear-End Collision Fires Caused By...	(a) friction sparks	**4.17**
		(b) a hot surface	4.17
		(c) electrical	**4.17**
	(2) Suppress A Gasoline Pool, Leak, Or Spray Fire		4
	(2a) Prevent Re-Ignition Of The Fire Due To	(a) a hot surface	**1**
		(b) electrical	**1**
		(b) gasoline trail stretching from vehicle	4
	(3) Retard Propagation Of A Gasoline Pool, Leak, Or Spray Fire Under The Rear-End Or Passenger Compartment		2.5
TOTAL			**12.5**

TABLE C-l - FINAL RATING CONFIGURATION (CONT.)

CATEGORY	SUBCATEGORY	DESCRIPTION	POINTS
C. ADDRESSES FIRES IN VEHICLES NOT INVOLVED IN COLLISIONS			**5 BONUS**
D. CRASHWORTHINESS			
		system activated by crash and provides protection when fire initiates	25
		rated for high G loads	4
		works without electrical power	4
		Flexible	4
		partially damaged can still function	4
		multiple activation means	4
		activated by heat or fire signature	**4**
TOTAL			**25 MAX**
E. PRODUCT RELIABILITY AND STAGE OF DEVELOPMENT		manufactured product has been performance tested in post-crash vehicle fires or meets relevant standards	**12.5**
		manufactured product has been tested in similar applications	**10**
		manufactured product could be used with modifications	**7.5**
		prototype built and tested	**5**
		theorized product - no reliable performance data available	**2.5**
TOTAL			**12.5**
F. WEIGHT		5 lbs. or under	**12.5**
		10 lbs. or under	**6**
		20 pounds or under	**3**
		over 20 lbs.	0
TOTAL			**12.5**
GRAND TOTAL			**100+5**

Sub-Category (3), "Retarding a Front-End Fire", was awarded 7.5 points. The points were split evenly between the potential fuels/combustibles since ignition is presumed. This "retarding" capability may be due to several possible features: (1) the product forming a burn-resistant barrier that does not let a fire penetrate; (2) a highly insulative barrier; or (3) even a combustible component characterized by very low heat release that contributes little to fire growth.

A similar criterion is applied to rear-end fires in Category B. It is presumed that gasoline is the only serious initial threat in the rear of the vehicle. Friction sparks (due to the crash), hot surfaces (muffler, catalytic converter) and electrical energy (tail light assemblies, fuel pump power) are included as ignition sources. A technology used in the rear is expected to provide protection, particularly if extinguishing, all the way to the front bulkhead, including the mitigation of pool fires under the car. Most of these under-car pool fires will originate from damage to the fuel tank area. Part (2) and (2a) of this section is split up into the capability to suppress the initial gasoline fire (4 points) and the capability to prevent re-ignition (6 points). The re-ignition value was made slightly higher than with the front-end fire due to the fact that large quantities of fuel can be released in a rear-end crash which can spread into a wide pool. The likelihood of any re-ignition source (such as the catalytic converter) igniting a widespread and easily ignitable fuel such as gasoline warranted its extra value in mitigation. Since the fuel is specified as gasoline in (2), no further sub-categories are needed. For (2a), the various ignition sources that are relevant to the rear configuration that could cause re-ignition are hot surfaces, electrical energy and a gasoline trail stretching from the vehicle. When a vehicle has a ruptured fuel tank and continues to move away from the initial impact location due to momentum transfer, the trail can be ignited some distance away and can spread to underneath the car. If a gasoline trail occurs, re-ignition can be mitigated only if some barrier is deposited across the trail, or over the entire pool fire under the car. Sub-Category (3), which represents retardation of gasoline fires in the rear scenario, has 2.5 points.

The next category awards 5 "bonus" points to technologies that can also address fires that are not due to a crash. These points are in addition to the 100 points assigned to the rating (giving a total maximum possible of 105 points). A large portion of the technologies reviewed should provide some measure of protection in the event of such fires.

Crashworthiness is evaluated in the next category. In terms of crashworthiness, an ideal technology is one that is activated by the crash itself. A product must be able to address the fire even if it is initiated several minutes after the impact event. Products (such as extinguishants) which persist by coating substances and fuel pools or remaining as a suspension in the air for long periods, might satisfy this criteria. Products that prevent fuel leakage would also qualify under these criteria. These types of technologies would be given the full category point value of 25 points.

Six other product features that promote crashworthiness are each given 4 points, with 24 points possible for products having all of the features. The feature of being "rated for high G-loads" suggests that the shock of the crash (or sudden bumping) will not disable the product before the fire erupts. If the product "works without electrical power," then it will not have to rely on an intact and functioning electrical system after the crash to function. Also, it may not initiate prematurely due to some shorting in the electrical system. Products that have their own internal power supply, such as batteries, would also qualify for credit. A product that is "flexible" can bend or deform in conformance with the deformed structure of the automobile after the crash, without inhibiting its capability to function afterwards. Other more rigid products may fracture, sever or become crushed, therefore becoming useless. The merits of this feature have been observed in preliminary crash tests done to date. The capability to be "partially damaged and still function" is also a valuable feature, given the high likelihood of at least some damage to installed mitigation technologies in high speed crashes. Products that have one or more components, which, when damaged render the whole product useless, would not qualify for this feature. Likewise, products with "multiple activation means" have a better chance of being initiated even if one or more of the activation means have been damaged. In some cases, the occupant in the vehicle might initiate the device by use of a pull handle or switch as an option. The feature "activated by heat or fire signature" suggests that the product will wait until it detects that an actual fire has begun before initiating itself. This will preserve its mitigating capability until the event begins and not prematurely exhaust its capability.

The category "Product Reliability and Stage of Development" was allocated 12.5 points. Each product received a point value corresponding to the following criteria. The highest value, 12.5 points, was assigned to manufactured products that have been performance tested in post-crash vehicle fires or meet relevant standards. These relevant standards may be Department of Transportation standards or even those used in special applications such as auto racing. Since there are a limited number of defined categories, some have somewhat broad definitions. For example, products which are currently used for fire protection in commercial vehicles were awarded 12.5 points. This point assignment was decided although the products might not have been tested in an actual crash event. This was allowed since standardized (or even specialized) tests of that nature are rare or non-existent. If some features of the product made it suspect regarding collision survivability, then exceptions were made. In contrast, products which have been used and demonstrated in similar applications, such as the marine, rail or airline industries (assuming on-board the vehicles), or military variants, were assigned 10 points. A product, which requires significant modifications to the current configuration, qualified for the next band and 7.5 points. If only a prototype of the concept has been built and tested, it would apply to the next band and receive 5 points. If the product is conceptual, and no relevant, reliable data on its function is available, it was awarded 2.5 points.

The final category, "Weight", was assigned 12.5 points. Points were assigned as seen in Table C- 1. Additional weight required for specialized brackets and installation hardware was not considered.

APPENDIX D. GROUND RULES USED IN APPLYING RATING

A listing of the principal assumptions used in applying the rating process to actual products is shown in Table D- 1. When further explanation is warranted, this section explains the rationale for and ramifications of applying these assumptions. The sizing and weight assumptions (l-10) were discussed in Section II, and are not discussed further. It should be noted that the fire resistant materials were assessed with “bulkhead” protection versus “no-bulkhead” protection in addition to their component replacement applications in the rating. This was done to see which variant was most beneficial in terms of total rating points. The trade-off of the benefits of additional fire scenarios addressed with bulkhead protection versus the penalty of additional weight was then evaluated.

Assumption 11. Some extinguishers had a detector or automatic initiator already installed in the extinguisher, while others did not. Since most extinguishers for automotive applications are installed with a detector, and in order to obtain comparable appraisals of the potential merits of different extinguisher products, each extinguisher was matched with a detector that would maximize its point rating. Options included using a detector made by the same manufacturer, one made by another manufacturer, a detection or initiation device already installed on the unit or none at all.

Assumption 12. The resultant extinguisher and detector pair were considered a single unit for rating purposes. The lower point values associated with either the extinguisher or the detector in the categories of “Crashworthiness” and “Product reliability and stage of development” was assigned to the resultant system. The exception to this requirement was in the category of “Crashworthiness” for the features “multiple activation means” and “activated by heat or fire signature”.

Assumption 13. It was assumed that dry chemicals, solid aerosols, water mist and AFFF are effective extinguishants in preventing fire re-ignition, whereas “clean” gaseous extinguishants and inert gases from gas generators are ineffective. Extinguishants that assume a gaseous state when discharged quickly disperse after release and do not provide re-ignition protection. Dry chemical powders lay down a protective barrier that can block the interaction of the fuel and heat source. Aqueous Film-Forming Foam, or AFFF, forms an effective barrier, or “film” between the fuel (burning fluid or solid surface) and the ignition source. This film can prevent ignition, as well as provide some cooling of hot surfaces. Water mist is marginal with respect to hot surface re-ignition, but has been shown to provide some level of effectiveness.

Assumption 14. A fire extinguishing system that is designed to protect the rear area of the car can also protect against some non-collision induced fires. A non-collision fire originating in the rear area could occur. It is assumed in this analysis that a non-collision fire originating from a failure of the fuel tank structure itself (since the tank body does not typically leak) is not likely. Therefore, technologies that relate solely to the fuel tank did not qualify as protecting against non-collision fires.

TABLE D-l - ASSUMPTIONS USED IN THE RATING PROCESS

#	ASSUMPTION
1	Used extinguishant mass requirements defined in Tables 3, 4 - added separate front and rear calculations for front/rear combination (assumed hardware customized to specified capacity)
2	Clean Agent, Dry Chemical, Water Mist, AFFF Systems - multiplied agent requirements by 2 to account for hardware weight (in these pressurized systems)
3	1.5x weight increase above extinguishant weight due to hardware of gas/aerosol generators
4	1.1x increase in weight due to hardware of powder panels
5	Inefficiency of tubular extinguisher storage configuration offsets reduced weight of plastic vs. metal containers (resulting in 2.0x hardware increase for pressurized extinguishants)
6	Fire Retardant/Intumescent/Ablative Coatings applied in 0.1" thickness on front bulkhead across 2' x 5' section, and on rear bulkhead/underneath car across 5' x 10' section
7	Assume approximate 15 gallon tank of two cubic feet - shape of two 1-foot adjacent cubes
8	Flame arrestor protects vapor canister (1/8 cubic foot assumed) in addition to fuel tank and as a barrier on each bulkhead
9	Crash resistant fuel tanks weigh no more than 5 lbs. over current conventional tanks
10	Fire resistant replacement materials not assumed to add weight to existing systems; Self-sealing fuel line components also included in that criteria
11	Matched best rated detector (typically linear pneumatic) to extinguishing systems, or whichever gave highest overall rating when incorporating features of both
12	Both extinguisher <u>and</u> detector must have various features in Parts D, E of rating for points in each (exception: "activated by heat or fire signature", "multiple activation means" in D)
13	Powder, aerosol, water mist, AFFF can prevent re-ignition; clean agent, inert gas cannot
14	Suppression systems can suppress non-collision fires in rear <u>if</u> a leak of fuel can ignite on exhaust components or ground ignition source (self-sealing fuel lines also – not fuel tanks)
15	12.5 points (section E) for commercial land vehicle use, 10 for military, marine, rail, etc.
16	Fire resistant barriers won't impede fire if damaged in crash (intumescents do), but "needs no electric", "rated for high g-loads", "multiple activation means", "activated by heat, fire"
17	Fire resistant replacement materials scored like #16 but don't burn, so function if damaged
18	Crash resistant fuel tanks, flame arrestor material, fluid shutoff valves and self-sealing fluid components prevent ignition from any source by preventing fluid availability
19	Fire resistant seat foam, air filters don't sufficiently address automotive post-collision fire
20	Paper board-based material not rated – questionable fire resistance in crash fire conditions
22	Handheld detector not rated due to lack of practical use of handheld device in crash event
23	Gas generators assumed crashworthy since airbag generators designed to survive crashes
24	Tubular system has "multi-activation means"(can be initiated at multiple locations)
25	If a system weight is less than one pound over the threshold of a higher point level in "Weight", system is attributed to the lighter weight and thus the higher point level
26	Linear detectors must have battery backup, or extinguishing systems the same, a frangible bulb, auto heat initiation or manual activation, to qualify for "needs no electrical power"
27	"Multi-activation means" for multiple detection types, not multiple spot detectors or linear
28	Linear pneumatic detectors "partially damaged, still function"; not linear thermal
29	Extinguisher initiation from airbag signal assumed to not assure protection until fire starts

Assumption 15. As was discussed previously, it was decided that a product would receive the full 12.5 points under the category "Product Reliability and Level of Development" if it is currently used on commercial highway vehicles. It was preferred that the products had been tested in a post-crash environment, but such data is primarily limited to the auto racing community. For this reason it was decided that use for fire safety in the automotive environment was sufficient to receive the full points in the category. Previous applications in other transportation types, including aviation, rail or marine, would receive 10 points, as well as use for military vehicle applications. Under the definitions of the category point bands, if a product had not been used in such applications, but virtually no product modifications are foreseen, then it may qualify for the 10 points as well. This is recommended since the next lower point band identifies the necessity of modifications to the product. Some of the coatings used in other industries may qualify for such an interpretation, as an example.

Assumption 16. It was assumed that the protective capability of fire resistant coatings and surface barriers would be compromised if they were damaged severely in a crash. Thus, these products were not awarded the 4 points for products "partially damaged, can still function" under "Crashworthiness". Flame arrestor material on the bulkheads was treated similarly. It was assumed that intumescent coatings would close any fractures that are created in a crash, although in subsequent testing at the National Institute of Standards and Technology, intumescent coatings were not shown to close open holes. All of the surface coatings are presumed to qualify for several additional "Crashworthiness" features. They are assumed to withstand the shock of a crash, and to have "multiple activation means", since they can stop the propagation of a flame at several locations. The coatings are also presumed to be "activated by heat, fire" since they will respond when impinged by heat or fire. Most of the coatings are not presumed to be "flexible", with the exception of one surveyed product, which identified flexibility as one of its unique properties over its competition.

Assumption 17. The fire resistant replacement materials and components, when used to replace existing components, will still function when damaged. They reduce the ignitability of such components and reduce the amount of combustible material available or heat released. If the fire resistant materials are applied to the bulkheads in addition to replacing existing materials, the increase of rating points awarded could be offset by the increase in weight; therefore, the choice whether to employ both to maximize points depended upon the material in consideration and the application area. This weight increase for bulkhead protection varied between materials. This influenced the decision for each application area, which frequently resulted in bulkhead protection for one area but not the other, or only for the combination scenario. In the rear area, only bulkhead protection was used, since only the prevention of gasoline fires was considered, and the retardation approach was the only option. When bulkhead protection was selected (with or without material substitution), the "partially damaged, can still function" feature under "Crash-worthiness" was no longer valid, since its fracture in a collision would compromise its retarding capability. One material, a fire resistant plastic wiring insulation, was only considered for that material substitution application. Intumescent/ablative materials were only evaluated in the bulkhead application, since they would not replace any existing components.

Assumption 18. The crash resistant fuel tanks, flame arrestor material (in the vapor canister), fluid shutoff valves and self-sealing fuel system components are anticipated to prevent gasoline or other fluid fires from initiating from any ignition source. They have this capability because they prevent the transport of combustible fluids to the proximity of ignition sources. These products receive high point values in categories A and/or B. Reticulated foam and the flame arrestor material in the fuel tank are limited to the prevention of the instantaneous ignition of fuel from crash-induced friction sparks, since they only prevent a sudden gush of fuel from the tank immediately after impact.

Assumption 19. Products such as fire resistant seat cushion materials and interior air filter materials are applied in vehicle areas that are not emphasized in this project. If a fire is established in the passenger compartment, fatalities or serious injuries could probably not be prevented. For these reasons these products were not rated.

Assumption 20. Certain thin fiber board-based products were determined to be of negligible benefit for this application. They were known to provide some fire resistance for small electrical smoldering fires and were used in passenger compartments of vehicles to reduce the amount of combustible material. Their disallowance was based upon knowledge and experience with these products and their expected inadequacy for potentially large-scale fires anticipated in the automobile collision scenario.

Assumptions 21,22. Handheld fire detectors or portable extinguishers, located in the passenger compartment and requiring active implementation by the passengers, were not rated. In the collision scenarios under consideration, it is not expected that the trapped passengers will be capable or mobile enough to operate the equipment or direct the extinguishant to the fire, which is most likely outside the passenger compartment.

Assumption 23. Self-explanatory.

Assumption 24. The tubular fire extinguishing systems qualified for the “multiple activation means” criteria under the “Crashworthiness” category because they initiate anywhere along their length where they are heated.

Assumption 25. If the final weight estimated for a rated product was within one pound of the maximum of the next higher (point-wise) weight band, the product was awarded the points for the next higher band. This was done to accommodate the likely inaccuracies in determining exact system weights, and to prevent products of the same technology type and similar weights from receiving significantly different scores. For example, if two products of the same technology type weighed 4.8 lbs. and 5.2 lbs. respectively, they would both receive 12.5 points for the “five lbs. or less” category to prevent an artificial point separation of the two.

Assumption 26. Fire detectors, including linear heat and pneumatic, must have electrical power to support a fire signal. Without a back up battery, they do not qualify for "works without electrical power". Similarly, extinguishing systems must use a frangible bulb, battery-powered detector or manual mechanism to qualify for "works without electrical power" (excluding the tubular system). If the unit auto-initiates at a pre-set temperature (such as with some gas generators), it would qualify. This assumes that no other power source is necessary to power a squib or other electro-mechanical device to open an extinguisher valve.

Assumption 27. "Multiple activation means" was not awarded to linear detectors or multiple spot detectors individually, because using such an approach is obvious and not a beneficial trait of the detection means itself. The detection systems can be initiated in multiple locations in the compartment, but the same type of signal is processed for each, and they converge at a single vulnerable signal processing location. This does not increase the number of alternative initiation paths (and likelihood of system initiation) if the system were damaged at that point, or if the stimulus required for that type of detection were not present. However, if two different types of detection were used in independent networks (for example, spot detectors with a separate linear circuit or a frangible bulb), then it qualified. It would provide several different means of initiation at separate sites, and increase the likelihood of extinguishing system initiation. The tubular system, however, as a discrete extinguishing system, can be initiated to begin extinguishing at one of numerous sites, even if damaged, and thus qualified for the designation.

Assumption 28. Linear pneumatic detectors were awarded the "partially damaged, still function" designation since, even if severed, they typically are sealed by the damage event at that location (according to the manufacturer). This allows them to retain their detection capability between the damage site and the signal processor. Electrical wire thermal linear detectors will typically short circuit at the damage site, however, and do not function as intended no qualify for the designation.

Assumption 29. One option for initiating the active systems is to trigger them off of the inertia switch of the air bag in the event of a collision. This early initiation of the system could result in the discharged extinguishant dispersing long before the fire initiates. Since such a fire can ignite several minutes after the collision, the possibility of this lost protection condition is significant enough to discourage its consideration at this time. Although some extinguishants may persist long enough to discourage fire re-ignitions shortly after their initial extinguishment, the possibly lengthy period noted here poses a more difficult challenge. This approach may show some promise with additional development and evaluation.

APPENDIX E: RATING SCORES

TABLE E-1 - RATING SCORES OF THE SURVEYED PRODUCTS

TECHNOLOGY PRODUCTS	DETECTOR TYPE	APPLICATION	FRONT END FIRE SCENARIOS ADDRESSED	REAR END FIRE SCENARIOS ADDRESSED	NON-COLLISION FIRES	CRASHWORTHINESS: ACTIVATED BY CRASH	RATED FOR HIGH G-LOADS	NO ELECTRICITY NEEDED	FLEXIBLE	DAMAGED, STILL FUNCTIONS	MULTIPLE ACTIVATION MEANS	ACTIVATED BY HEAT, FIRE	TOTAL	STAGE OF DEVELOPMENT	WEIGHT: ACTUAL WEIGHT	WEIGHT POINTS	TOTAL
ACTIVE SYSTEMS																	
LINEAR PNEUMATIC DETECTOR 1	A	F			5		x		X	X		X	16	12.5	0.5	12.5	46
LINEAR PNEUMATIC DETECTOR 1		R			5		x		X	X		X	16	12.5	0.5	12.5	46
LINEAR PNEUMATIC DETECTOR 1		F/R			5		x		X	X		X	16	12.5	1	12.5	46
SPOT/LINEAR PNEUMATIC DETECTOR 1	B	F			5		x	x	X	X	X	X	24	12.5	2.1	12.5	54
SPOT/LINEAR PNEUMATIC DETECTOR 1		R			5		x	x	X	X	X	X	24	12.5	2.1	12.5	54
SPOT/LINEAR PNEUMATIC DETECTOR 1		F/R			5		x	x	X	X	X	X	24	12.5	4.2	12.5	54
OPTICAL DETECTOR 1	C	F			5		x					X	8	12.5	0.7	12.5	38
OPTICAL DETECTOR 1		R			5		x					X	8	12.5	0.7	12.5	38
OPTICAL DETECTOR 1		F/R			5		x					X	8	12.5	1.4	12.5	38
HEAT LINEAR DETECTOR 1	D	F			5				X			X	8	12.5	0.5	12.5	38
HEAT LINEAR DETECTOR 1		R			5				X			X	8	12.5	0.5	12.5	38
HEAT LINEAR DETECTOR 1		F/R			5				X			X	8	12.5	1	12.5	38
HEAT LINEAR DETECTOR 2	D	F			5		x	x	X			X	16	12.5	10.5	6	39.5
HEAT LINEAR DETECTOR 2		R			5		x	x	X			X	16	12.5	10.5	6	39.5
HEAT LINEAR DETECTOR 2		F/R			5		x	x	X			X	16	12.5	11	6	39.5
MACHINE VISION DETECTOR 1	E	F			5		x		X	X		X	16	5	2	12.5	38.5
MACHINE VISION DETECTOR 1		R			5		x		X	X		X	16	5	2	12.5	38.5
MACHINE VISION DETECTOR 1		F/R			5		x		X	X		X	16	5	4	12.5	38.5
OPTICAL DETECTOR 2	C	F			5							X	4	12.5	0.5	12.5	34
OPTICAL DETECTOR 2		R			5							X	4	12.5	0.5	12.5	34
OPTICAL DETECTOR 2		F/R			5							X	4	12.5	1	12.5	34
GAS DETECTOR 1	F	F			5		x						4	12.5	4.75 +	12.5	34
GAS DETECTOR 1		R			5		X						4	12.5	4.75 +	12.5	34
GAS DETECTOR 1		F/R			5		X						4	12.5	5.5	12.5	34
OPTICAL DETECTOR 3	C	F			5		X					X	8	10	1.65	12.5	35.5
OPTICAL DETECTOR 3		R			5		X					X	8	10	1.65	12.5	35.5
OPTICAL DETECTOR 3		F/R			5		X					X	8	10	3.3	12.5	35.5
OPTICAL DETECTOR 4	C	F			5		X					X	8	10	6.5	6	29
OPTICAL DETECTOR 4		R			5		X					X	8	10	6.5	6	29
OPTICAL DETECTOR 4		F/R			5		X					X	8	10	13	3	26
HEAT LINEAR DETECTOR 3	D	F			5				X			X	8	10	?	0	23
HEAT LINEAR DETECTOR 3		R			5				X			X	8	10	?	0	23
HEAT LINEAR DETECTOR 3		F/R			5				X			X	8	10	?	0	23
CONV. DRY CHEMICAL 1		F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	6.98	6	65.5
CONV. DRY CHEMICAL 1		R		2,2a,a-c (10)	5			X			X	X	12	12.5	14.54	3	42.5
CONV. DRY CHEMICAL 1		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	21.52	0	69.5

ASSUMPTIONS (APPENDIX D)

TECHNOLOGY PRODUCTS	APPLICATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
LINEAR PNEUMATIC DETECTOR 1	F															X											X	X	X	
LINEAR PNEUMATIC DETECTOR 1	R															X											X	X	X	
LINEAR PNEUMATIC DETECTOR 1	F/R															X											X	X	X	
SPOT/LINEAR PNEUMATIC DETECTOR 1	F															X											X	X	X	
SPOT/LINEAR PNEUMATIC DETECTOR 1	R															X											X	X	X	
SPOT/LINEAR PNEUMATIC DETECTOR 1	F/R															X											X	X	X	
OPTICAL DETECTOR 1	F															X												X		
OPTICAL DETECTOR 1	R															X												X		
OPTICAL DETECTOR 1	F/R															X												X		
HEAT LINEAR DETECTOR 1	F															X											X	X	X	
HEAT LINEAR DETECTOR 1	R															X											X	X	X	
HEAT LINEAR DETECTOR 1	F/R															X											X	X	X	
HEAT LINEAR DETECTOR 2	F															X										X	X	X	X	
HEAT LINEAR DETECTOR 2	R															X										X	X	X	X	
HEAT LINEAR DETECTOR 2	F/R															X										X	X	X	X	
MACHINE VISION DETECTOR 1	F															X												X		
MACHINE VISION DETECTOR 1	R															X												X		
MACHINE VISION DETECTOR 1	F/R															X												X		
OPTICAL DETECTOR 2	F															X												X		
OPTICAL DETECTOR 2	R															X												X		
OPTICAL DETECTOR 2	F/R															X												X		
GAS DETECTOR 1	F															X												X		
GAS DETECTOR 1	R															X												X		
GAS DETECTOR 1	F/R															X										X		X		
OPTICAL DETECTOR 3	F															X												X		
OPTICAL DETECTOR 3	R															X												X		
OPTICAL DETECTOR 3	F/R															X												X		
OPTICAL DETECTOR 4	F															X												X		
OPTICAL DETECTOR 4	R															X												X		
OPTICAL DETECTOR 4	F/R															X												X		
HEAT LINEAR DETECTOR 3	F															X											X	X	X	
HEAT LINEAR DETECTOR 3	R															X											X	X	X	
HEAT LINEAR DETECTOR 3	F/R															X											X	X	X	
CONV. DRY CHEMICAL 1	F	X	X											X		X											X	X		X
CONV. DRY CHEMICAL 1	R	X	X											X	X	X											X	X		X
CONV. DRY CHEMICAL 1	F/R	X	X											X		X											X	X		X

TABLE E-1 - RATING SCORES OF THE SURVEYED PRODUCTS (CONT.)

TECHNOLOGY PRODUCTS	DETECTOR TYPE	APPLICATION	FRONT END FIRE SCENARIOS ADDRESSED	REAR END FIRE SCENARIOS ADDRESSED	CRASHWORTHINESS: NON-COLLISION FIRES	ACTIVATED BY CRASH	RATED FOR HIGH G-LOADS	NO ELECTRICITY NEEDED	FLEXIBLE	DAMAGED, STILL FUNCTIONS	MULTIPLE ACTIVATION MEAN	ACTIVATED BY HEAT, FIRE	TOTAL	STAGE OF DEVELOPMENT	WEIGHT: ACTUAL WEIGHT	WEIGHT POINTS	TOTAL
CONV. DRY CHEMICAL 2		F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	10	6.48	6	63
CONV. DRY CHEMICAL 2		R		2,2a,a-c (10)	5			X			X	X	12	10	14.04	3	40
CONV. DRY CHEMICAL 2		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	10	20.52	3	70
CONV. DRY CHEMICAL 3	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	6.98	6	65.5
CONV. DRY CHEMICAL 3		R		2,2a,a-c (10)	5			X			X	X	12	12.5	14.54	3	42.5
CONV. DRY CHEMICAL 3		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	21.52	0	69.5
CONV. DRY CHEMICAL 4	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	6.95	6	65.5
CONV. DRY CHEMICAL 4		R		2,2a,a-c (10)	5			X			X	X	12	12.5	14.54	3	42.5
CONV. DRY CHEMICAL 4		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	21.52	0	69.5
CONV. DRY CHEMICAL 5	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	6.98	6	65.5
CONV. DRY CHEMICAL 5		R		2,2a,a-c (10)	5			X			X	X	12	12.5	14.54	3	42.5
CONV. DRY CHEMICAL 5		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	21.52	0	69.5
CONV. DRY CHEMICAL 6	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	6.98	6	65.5
CONV. DRY CHEMICAL 6		R		2,2a,a-c (10)	5			X			X	X	12	12.5	14.54	3	42.5
CONV. DRY CHEMICAL 6		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	21.52	0	69.5
CONV. DRY CHEMICAL 7	B	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	8.58	6	65.5
CONV. DRY CHEMICAL 7		R		2,2a,a-c (10)	5			X			X	X	12	12.5	16.14	3	42.5
CONV. DRY CHEMICAL 7		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	24.72	0	69.5
CONV. DRY CHEMICAL 8	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	6.98	6	55.5
CONV. DRY CHEMICAL 8		R		2,2a,a-c (10)	5			X			X	X	12	12.5	14.54	3	32.5
CONV. DRY CHEMICAL 8		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	21.52	0	59.5
CONV. AFFF 1	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	10	6.98	6	63
CONV. AFFF 1		R		2,2a,a-c (10)	5			X			X	X	12	10	14.54	3	40
CONV. AFFF 1		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	10	21.52	3	67
TUBULAR/DRY CHEMICAL		F	2a,i-iii,2b,a-b,(30)		5			X	X		X	X	16	5	6.48	6	62
TUBULAR/DRY CHEMICAL		R		2,2a,a-c (10)	5			X	X		X	X	16	5	14.04	3	39
TUBULAR/DRY CHEMICAL		F/R	2a,i-iii,2b (30)	2,2a,a-c (10)	5			X	X		X	X	16	5	20.52	3	69
AEROSOL 1	A	F	2a,i-iii,2b, a,b (30)		5			X			X	X	12	10	3.2	12.5	69.5
AEROSOL 1		R		2,2a,a-c (10)	5			X			X	X	12	10	6.35	6	43
AEROSOL 1		F/R	2a,i-iii,2b, a,b (30)	2,2a,a-c (10)	5			X			X	X	12	10	9.55	6	73
AEROSOL 2		F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	5	2.7	12.5	64.5
AEROSOL 2		R		2,2a,a-c (10)	5			X			X	X	12	5	5.85	12.5	44.5
AEROSOL 2		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	5	8.5	6	68
AEROSOL 3	B	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	5	4.8	12.5	64.5
AEROSOL 3		R		2,2a,a-c (10)	5			X			X	X	12	5	7.95	6	38
AEROSOL 3		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	5	12.75	3	65

TECHNOLOGY PRODUCTS	APPLICATION	ASSUMPTIONS (APPENDIX D): 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
CONV. DRY CHEMICAL 2	F	X	X											X		X												X		X
CONV. DRY CHEMICAL 2	R	X	X											X	X	X												X		X
CONV. DRY CHEMICAL 2	F/R	X	X											X		X										X		X		X
CONV. DRY CHEMICAL 3	F	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 3	R	X	X									X	X	X	X	X											X	X		X
CONV. DRY CHEMICAL 3	F/R	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 4	F	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 4	R	X	X									X	X	X	X	X											X	X		X
CONV. DRY CHEMICAL 4	F/R	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 5	F	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 5	R	X	X									X	X	X	X	X											X	X		X
CONV. DRY CHEMICAL 5	F/R	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 6	F	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 6	R	X	X									X	X	X	X	X											X	X		X
CONV. DRY CHEMICAL 6	F/R	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 7	F	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 7	R	X	X									X	X	X	X	X											X	X		X
CONV. DRY CHEMICAL 7	F/R	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 8	F	X	X									X	X	X		X											X	X		X
CONV. DRY CHEMICAL 8	R	X	X									X	X	X	X	X											X	X		X
CONV. DRY CHEMICAL 8	F/R	X	X									X	X	X		X											X	X		X
CONV. AFFF 1	F	X	X									X	X	X		X											X	X		X
CONV. AFFF 1	R	X	X									X	X	X	X	X											X	X		X
CONV. AFFF 1	F/R	X	X									X	X	X		X											X	X		X
TUBULAR/DRY CHEMICAL	F	X				X								X		X									X					X
TUBULAR/DRY CHEMICAL	R	X				X								X	X	X									X					X
TUBULAR/DRY CHEMICAL	F/R	X				X								X		X									X					X
AEROSOL 1	F	X		X								X	X	X		X											X	X		X
AEROSOL 1	R	X		X								X	X	X	X	X											X	X		X
AEROSOL 1	F/R	X		X								X	X	X		X											X	X		X
AEROSOL 2	F	X		X										X	X	X												X		X
AEROSOL 2	R	X		X										X	X	X											X	X		X
AEROSOL 2	F/R	X		X										X		X												X		X
AEROSOL 3	F	X		X								X	X	X		X											X	X		X
AEROSOL 3	R	X		X								X	X	X	X	X											X	X		X
AEROSOL 3	F/R	X		X								X	X	X		X											X	X		X

TABLE E-1 - RATING SCORES OF THE SURVEYED PRODUCTS (CONT.)

TECHNOLOGY PRODUCTS	DETECTOR TYPE	APPLICATION	FRONT END FIRE SCENARIOS ADDRESSED	REAR END FIRE SCENARIOS ADDRESSED	NON-COLLISION FIRES	CRASHWORTHINESS								STAGE OF DEVELOPMENT	WEIGHT		TOTAL	ASSUMPTIONS (APPENDIX D)																												
						ACTIVATED BY CRASH	RATED FOR HIGH G-LOADS	NO ELECTRICITY NEEDED	FLEXIBLE	DAMAGED CAN STILL FUNCTION	MULTIPLE ACTIVATION MEANS	ACTIVATED BY HEAT, FIRE	TOTAL		ACTUAL WEIGHT	WEIGHT POINTS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
AEROSOL 4	B	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	2.5	4.8	12.5	62	X		X								X	X	X		X											X	X		X
AEROSOL 4		R		2,2a,a-c (10)	5			X			X	X	12	2.5	7.95	6	35.5	X		X								X	X	X	X	X											X	X		X
AEROSOL 4		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	2.5	12.75	3	62.5	X		X								X	X	X		X											X	X		X
CONV. WATER MIST 1	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	10	9.14	6	63	X	X									X	X	X		X											X	X		X
CONV. WATER MIST 1		R		2,2a,a-c (10)	5			X			X	X	12	10	19.22	3	40	X	X									X	X	X	X	X											X	X		X
CONV. WATER MIST 1		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	10	28.36	0	67	X	X									X	X	X		X											X	X		X
CONV. WATER MIST 2	A	F	2a,i-iii,2b,a-b,(30)		5			X			X	X	12	12.5	9.14	6	65.5	X	X									X	X	X		X											X	X		X
CONV. WATER MIST 2		R		2,2a,a-c (10)	5			X			X	X	12.125	12.5	19.22	3	42.5	X	X									X	X	X	X	X											X	X		X
CONV. WATER MIST 2		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5			X			X	X	12	12.5	28.36	0	69.5	X	X									X	X	X		X											X	X		X
GAS GEN./POWDER 1	A	F	2a,i-iii,2b,a-b,(30)		5		X	X			X	X	16	2.5	5.36	12.5	66	X		X								X	X	X		X								X		X	X	X		X
GAS GEN./POWDER 1		R		2,2a,a-c (10)	5		X	X			X	X	16	2.5	11.03	3	36.5	X		X								X	X	X	X	X								X			X	X		X
GAS GEN./POWDER 1		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5		X	X			X	X	16	2.5	16.39	3	66.5	X		X								X	X	X		X								X			X	X		X
GAS GEN./WATER MIST 1	B	F	2a,i-iii,2b,a-b,(30)		5		X	X			X	X	16	2.5	8.58	6	59.5	X		X								X	X	X		X								X			X	X		X
GAS GEN./WATER MIST 1		R		2,2a,a-c (10)	5		X	X			X	X	16	2.5	16.14	3	36.5	X		X								X	X	X	X	X								X			X	X		X
GAS GEN./WATER MIST 1		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5		X	X			X	X	16	2.5	24.72	0	63.5	X		X								X	X	X		X								X			X	X		X
GAS GEN./INERT GAS 1	B	F	2a,i-iii (18)		5		X	X			X	X	16	12.5	12.9	3	54.5	X		X								X	X	X		X								X			X	X		X
GAS GEN./INERT GAS 1		R		2 (4)	5		X	X			X	X	16	12.5	25.56	0	37.5	X		X								X	X	X	X	X								X			X	X		X
GAS GEN./INERT GAS 1		F/R	2a,i-iii (18)	2 (4)	5		X	X			X	X	16	12.5	38.4	0	55.5	X		X								X	X	X		X								X			X	X		X
GAS GEN./INERT GAS 2		F	2a,i-iii (18)		5		X	X			X	X	16	10	9.72	6	55	X		X										X		X								X				X		X
GAS GEN./INERT GAS 2		R		2 (4)	5		X	X			X	X	16	10	21.06	0	35	X		X										X	X	X								X				X		X
GAS GEN./INERT GAS 2		F/R	2a,i-iii (18)	2 (4)	5		X	X			X	X	16	10	30.76	9	53	X		X										X		X								X				X		X
EXPLOSION SUPPRESSION/DRY CHEM. 1	C	F	2a,i-iii,2b,a-b,(30)		5							X	4	10	7.18	6	55	X	X									X	X	X		X														X
EXPLOSION SUPPRESSION/DRY CHEM. 1		R		2,2a,a-c (10)	5							X	4	10	14.74	3	32	X	X									X	X	X	X	X														X
EXPLOSION SUPPRESSION/DRY CHEM. 1		F/R	2a,i-iii,2b,a-b,(30)	2,2a,a-c (10)	5							X	4	10	21.92	0	59	X	X									X	X	X		X														X
EXPLOSION SUPPRESSION/CLEAN AGT. 1	C	F	2a,i-iii (18)		5							X	4	10	11.5	3	40	X	X									X	X	X		X														X
EXPLOSION SUPPRESSION/CLEAN AGT. 1		R		2 (4)	5							X	4	10	24.1	0	23	X	X									X	X	X	X	X														X
EXPLOSION SUPPRESSION/CLEAN AGT. 1		F/R	2a,i-iii (18)	2 (4)	5							X	4	10	35.6	0	41	X	X									X	X	X		X														X
CONV. CLEAN AGENT 1		F	2a,i-iii (18)		5			X			X	X	12	12.5	10.8	6	53.5	X	X											X	X	X										X	X	X		X
CONV. CLEAN AGENT 1		R		2 (4)	5			X			X	X	12	12.5	23.4	0	33.5	X	X											X	X	X											X	X		X
CONV. CLEAN AGENT 1		F/R	2a,i-iii (18)	2 (4)	5			X			X	X	12	12.5	34.2	0	51.5	X	X											X	X	X											X	X		X
CONV. CLEAN AGENT 2	A	F	2a,i-iii (18)		5			X			X	X	12	12.5	11.3	3	50.5	X	X									X	X	X		X											X	X		X
CONV. CLEAN AGENT 2		R		2 (4)	5			X			X	X	12	12.5	25.9	0	33.5	X	X									X	X	X	X	X											X	X		X
CONV. CLEAN AGENT 2		F/R	2a,i-iii (18)	2 (4)	5			X			X	X	12	12.5	35.2	0	51.5	X	X									X	X	X		X											X	X		X
CONV. CLEAN AGENT 3	B	F	2a,i-iii (18)		5			X			X	X	12	12.5	11.9	3	50.5	X	X									X	X	X		X											X	X		X
CONV. CLEAN AGENT 3		R		2 (4)	5			X			X	X	12	12.5	25.5	0	33.5	X	X									X	X	X	X	X											X	X		X
CONV. CLEAN AGENT 3		F/R	2a,i-iii (18)	2 (4)	5			X			X	X	12	12.5	38.4	0	51.5	X	X									X	X	X		X											X	X		X

TABLE E-1 - RATING SCORES OF THE SURVEYED PRODUCTS (CONT.)

TECHNOLOGY PRODUCTS	DETECTOR TYPE	APPLICATION	FRONT END FIRE SCENARIOS ADDRESSED	REAR END FIRE SCENARIOS ADDRESSED	NON-COLLISION FIRES	CRASHWORTHINESS: ACTIVATED BY CRASH	RATED FOR HIGH G-LOADS	NO ELECTRICITY NEEDED	FLEXIBLE	DAMAGED CAN STILL FUNCTIO	MULTIPLE ACTIVATION MEANS	ACTIVATED BY HEAT, FIRE	TOTAL	STAGE OF DEVELOPMENT	WEIGHT: ACTUAL WEIGHT	WEIGHT POINTS	TOTAL
CONV. CLEAN AGENT 4		F	2a,i-iii (18)		5			X			X	X	12	10	10.8	6	51
CONV. CLEAN AGENT 4		R		2 (4)	5			X			X	X	12	10	23.4	0	31
CONV. CLEAN AGENT 4		F/R	2a,i-iii (18)	2 (4)	5			X			X	X	12	10	34.2	0	49
CONV. CLEAN AGENT 5		F	2a,i-iii (18)		5			X			X	X	12	12.5	10.8	6	53.5
CONV. CLEAN AGENT 5		R		2 (4)	5			X			X	X	12	12.5	23.4	0	33.5
CONV. CLEAN AGENT 5		F/R	2a,i-iii (18)	2 (4)	5			X			X	X	12	12.5	34.2	0	51.5
CONV. CLEAN AGENT 6	A	F	2a,i-iii (18)		5			X			X	X	12	12.5	10	6	48
CONV. CLEAN AGENT 6		R		2 (4)	5			X			X	X	12	12.5	10	0	31
CONV. CLEAN AGENT 6		F/R	2a,i-iii (18)	2 (4)	5			X			X	X	12	12.5	10	0	49
PASSIVE SYSTEMS																	
SELF-SEALING FLUID COMPONENTS 1		F	1b,i-iii,1c,i-iii (28.2)		5	X							25	12.5	0 +	12.5	83.2
SELF-SEALING FLUID COMPONENTS 1		R		1a-c (12.5)	5	X							25	12.5	0 +	12.5	67.5
SELF-SEALING FLUID COMPONENTS 1		F/R	1b,i-iii,1c,i-iii (28.2)	1a-c (12.5)	5	X							25	12.5	0 +	12.5	95.7
FLUID SHUTOFF DEVICE 1		F	1b,i-iii,1c,i-iii (28.2)		5	X							25	10	0.1 +	12.5	80.7
FLUID SHUTOFF DEVICE 1		R															
FLUID SHUTOFF DEVICE 1		F/R	1b,i-iii,1c,i-iii (28.2)		5	X							25	10	0.1 +	12.5	80.7
FLUID SHUTOFF DEVICE 2		F	1b,i-iii,1c,i-iii (28.2)		0	X							25	5	5 ?	12.5	70.7
FLUID SHUTOFF DEVICE 2		R			0												
FLUID SHUTOFF DEVICE 2		F/R	1b,i-iii,1c,i-iii (28.2)		0	X							25	5	5 ?	12.5	70.7
FLUID SHUTOFF DEVICE 3		F	1b,i-iii,1c,i-iii (28.2)		5	X							25	5	1 +	12.5	75.7
FLUID SHUTOFF DEVICE 3		R															
FLUID SHUTOFF DEVICE 3		F/R	1b,i-iii,1c,i-iii (28.2)		5	X							25	5	1 +	12.5	75.7
CRASH RES. TANK 1		F															
CRASH RES. TANK 1		R		1a-c (12.5)		X							25	10	5 -	12.5	60
CRASH RES. TANK 1		F/R		1a-c (12.5)		X							25	10	5 -	12.5	60
CRASH RES. TANK 2		F															
CRASH RES. TANK 2		R		1a-c (12.5)		X							25	12.5	5 -	12.5	62.5
CRASH RES. TANK 2		F/R		1a-c (12.5)		X							25	12.5	5 -	12.5	62.5
CRASH RES. TANK 3		F															
CRASH RES. TANK 3		R		1a-c (12.5)		X							25	10	5 -	12.5	60
CRASH RES. TANK 3		F/R		1a-c (12.5)		X							25	10	5 -	12.5	60
FLAME ARRESTOR 1		F	3a,1b,i-iii,c (19.1)		5		X	X	X		X	X	20	10	0.6	12.5	66.6
FLAME ARRESTOR 1		R		1a,3 (6.67)	5		X	X	X		X	X	20	10	5.5	12.5	54.17
FLAME ARRESTOR 1		F/R	3a,1b,i-iii,c (19.1)	1a,3 (6.67)	5		X	X	X		X	X	20	10	6.1	6	66.77
RETICULATED FOAM 1		F															
RETICULATED FOAM 1		R		1a (4.17)	0		X	X	X	X	X	X	24	12.5	2.7	12.5	53.17
RETICULATED FOAM 1		F/R		1a (4.17)	0		X	X	X	X	X	X	24	12.5	2.7	12.5	53.17

ASSUMPTIONS (APPENDIX D)

TECHNOLOGY PRODUCTS	APPLICATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
CONV. CLEAN AGENT 4	F	X	X											X		X										X		X		X
CONV. CLEAN AGENT 4	R	X	X											X	X	X												X		X
CONV. CLEAN AGENT 4	F/R	X	X											X		X												X		X
CONV. CLEAN AGENT 5	F	X	X											X		X										X	X	X		X
CONV. CLEAN AGENT 5	R	X	X											X	X	X											X	X		X
CONV. CLEAN AGENT 5	F/R	X	X											X		X											X	X		X
CONV. CLEAN AGENT 6	F	X	X									X	X	X		X											X	X		X
CONV. CLEAN AGENT 6	R	X	X									X	X	X	X	X											X	X		X
CONV. CLEAN AGENT 6	F/R	X	X									X	X	X		X											X	X		X
PASSIVE SYSTEMS																														
SELF-SEALING FLUID COMPONENTS 1	F										X				X	X			X											
SELF-SEALING FLUID COMPONENTS 1	R										X				X	X			X											
SELF-SEALING FLUID COMPONENTS 1	F/R										X				X	X			X											
FLUID SHUTOFF DEVICE 1	F															X			X											
FLUID SHUTOFF DEVICE 1	R																													
FLUID SHUTOFF DEVICE 1	F/R															X			X											
FLUID SHUTOFF DEVICE 2	F															X			X											
FLUID SHUTOFF DEVICE 2	R																													
FLUID SHUTOFF DEVICE 2	F/R															X			X											
FLUID SHUTOFF DEVICE 3	F															X			X											
FLUID SHUTOFF DEVICE 3	R																													
FLUID SHUTOFF DEVICE 3	F/R															X			X											
CRASH RES. TANK 1	F																													
CRASH RES. TANK 1	R							X		X						X			X											
CRASH RES. TANK 1	F/R							X		X						X			X											
CRASH RES. TANK 2	F																													
CRASH RES. TANK 2	R							X		X						X			X											
CRASH RES. TANK 2	F/R							X		X						X			X											
CRASH RES. TANK 3	F																													
CRASH RES. TANK 3	R							X		X					X	X			X											
CRASH RES. TANK 3	F/R							X		X					X	X			X											
FLAME ARRESTOR 1	F						X	X	X							X	X		X											
FLAME ARRESTOR 1	R						X	X	X							X	X		X							X				
FLAME ARRESTOR 1	F/R						X	X	X							X	X		X											
RETICULATED FOAM 1	F																													
RETICULATED FOAM 1	R							X								X	X		X											
RETICULATED FOAM 1	F/R							X								X	X		X											

TABLE E-l - RATING SCORES OF THE SURVEYED PRODUCTS (CONT.)

TECHNOLOGY PRODUCTS	DETECTOR TYPE	APPLICATION	FRONT END FIRE SCENARIOS ADDRESSED	REAR END FIRE SCENARIOS ADDRESSED	NON-COLLISION FIRES	CRASHWORTHINESS CRASHWORTHINESS: ACTIVATED BY CRASH	RATED FOR HIGH G-LOADS	NO ELECTRICITY NEEDED	FLEXIBLE	DAMAGED CAN STILL FUNCTIO	MULTIPLE ACTIVATION MEANS	ACTIVATED BY HEAT, FIRE	TOTAL	STAGE OF DEVELOPMENT	WEIGHT: ACTUAL WEIGHT	WEIGHT POINTS	TOTAL
RETICULATED FOAM 2		F											0				0
RETICULATED FOAM 2		R		1a (4.17)			x	x	x	x	x	x	24	10	2.81	12.5	0.67
RETICULATED FOAM 2		F/R		1a (4.17)			X	X	X	X	X	X	24	10	2.81	12.5	0.67
POWDER PANEL 1		F															0
POWDER PANEL 1		R		1a-c (12.51)			X						25	10	7.72	6	i3.51
POWDER PANEL 1		F/R		la-c (12.51)			X						25	10	7.72	6	i3.51
ENGINE SHUTOFF 1		F	1aii,bii,cii (14.1)		5							x	4	10	1	12.5	45.6
ENGINE SHUTOFF 1		R															0
ENGINE SHUTOFF 1		F/R	1aii,bii,cii (14.1)		5							v	A	10	1	12.5	45.6
FIRE RESISTANT MATERIALS																	
FIRE RESISTANT PLASTICS 1		F	1a,i-ii (9.4)		5		X	X	X	X	X	X	24	12.5	0	12.5	63.4
FIRE RESISTANT PLASTICS 1		R		3 (2.5) (bulkhead)	5		x	x	x		x	x	20	12.5	15.63	0	40
FIRE RESISTANT PLASTICS 1		F/R	1a,i-ii (9.4)		5		X	X	X	X	X	X	24	12.5	0	12.5	63.4
FIRE RESISTANT PLASTICS 2		F	1a,i-ii (9.4)		5		x	x		x	x	x	20	10	0	12.5	56.9
FIRE RESISTANT PLASTICS 2		R		3 (2.5) (bulkhead)	5		x	x			x	x	16	10	39	0	33.5
FIRE RESISTANT PLASTICS 2		F/R	1a,i-ii (9.4)		5		x	x		x	x	x	20	10	0	12.5	56.9
FIRE RESISTANT PLASTICS 3		F	1a,i-ii (9.4)		5		X	X	X	X	X	X	24	7.5	0 ?	12.5	58.4
FIRE RESISTANT PLASTICS 3		R															0
FIRE RESISTANT PLASTICS 3		F/R	1a,i-ii (9.4)		5		X	X	X	X	X	X	24	7.5	07	12.5	56.4
FIRE RESISTANT PLASTICS 4		F	1a,i-ii,3b-c (14.4) (bulkhead)		5		x	x			x	x	16	10	0.17	12.5	57.9
FIRE RESISTANT PLASTICS 4		R		3 (2.5) (bulkhead)	5		x	x			X	X	16	10	0.65	12.5	46
FIRE RESISTANT PLASTICS 4		F/R	1a,i-ii,3b-c (14.4) (bulkhead)	3 (2.5) (bulkhead)	5		x	x			X	X	16	10	1.02	12.5	60.4
FIRE RESISTANT FABRICS 1		F	1 a,i-ii,3b-c (14.4) (bulkhead)		5		x	x	x		x	x	20	10	3.13	12.5	61.9
FIRE RESISTANT FABRICS 1		R		3 (2.5) (bulkhead'	5		x	x	x		x	x	20	10	15.65	3	40.5
FIRE RESISTANT FABRICS 1		F/R	1 a,i-ii (9.4)		5		x	x	x	x	x	x	24	10	0	3	60.9
FIRE RESISTANT FABRICS 2		F	1 a,I-ii,3b-c (14.4) (bulkhead)		5			X			x	x	12	10	3.13	12.5	53.9
FIRE RESISTANT FABRICS 2		R		3 (2.5) (bulkhead	5			X			x	x	15	10	15.65	3	32.5
FIRE RESISTANT FABRICS 2		F/R	3a-c (7.5)		5			X		x	x	x	16	10	0	0	52.9
FIRE RESISTANT FABRICS 3		F														0	0
FIRE RESISTANT FABRICS 3		R														0	0
FIRE RESISTANT FABRICS 3		FIR														0	0
FIRE RESISTANT FABRICS 4		F														0	0
FIRE RESISTANT FABRICS 4		R														0	0
FIRE RESISTANT FABRICS 4		F/R														0	0

TECHNOLOGY PRODUCTS	APPLICATION	ASSUMPTIONS (APPENDIX D): 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
RETICULATED FOAM 2	F																													
RETICULATED FOAM 2	R							X								X	X		X											
RETICULATED FOAM 2	F/R							X								X	X		X											
POWDER PANEL 1	F																													
POWDER PANEL 1	R	X			X																									
POWDER PANEL 1	F/R	X			X																									
ENGINE SHUTOFF 1	F															X			X											
ENGINE SHUTOFF 1	R																													
ENGINE SHUTOFF 1	F/R															X			X											
FIRE RESISTANT MATERIALS																														
FIRE RESISTANT PLASTICS 1	F										X					X		X												
FIRE RESISTANT PLASTICS 1	R						X									X	X													
FIRE RESISTANT PLASTICS 1	F/R										X					X		X												
FIRE RESISTANT PLASTICS 2	F										X					X		X												
FIRE RESISTANT PLASTICS 2	R						X									X	X													
FIRE RESISTANT PLASTICS 2	F/R										X					X		X												
FIRE RESISTANT PLASTICS 3	F										X					X		X												
FIRE RESISTANT PLASTICS 3	R																													
FIRE RESISTANT PLASTICS 3	F/R										X					X		X												
FIRE RESISTANT PLASTICS 4	F						X				X					X	X													
FIRE RESISTANT PLASTICS 4	R						X				X					X	X													
FIRE RESISTANT PLASTICS 4	F/R						X				X					X	X													
FIRE RESISTANT FABRICS 1	F						X				X					X	X													
FIRE RESISTANT FABRICS 1	R						X				X					X	X													
FIRE RESISTANT FABRICS 1	F/R						X				X					X		X												
FIRE RESISTANT FABRICS 2	F						X				X					X	X													
FIRE RESISTANT FABRICS 2	R						X				X					X	X													
FIRE RESISTANT FABRICS 2	F/R										X					X		X												
FIRE RESISTANT FABRICS 3	F																				X									
FIRE RESISTANT FABRICS 3	R																				X									
FIRE RESISTANT FABRICS 3	FIR																				X									
FIRE RESISTANT FABRICS 4	F																			X										
FIRE RESISTANT FABRICS 4	R																			X										
FIRE RESISTANT FABRICS 4	F/R																			X										

TABLE E-3 - RATING SCORES OF THE SURVEYED PRODUCTS (CONT.)

TECHNOLOGY PRODUCTS	DETECTOR TYPE	APPLICATION	FRONT END FIRE SCENARIOS ADDRESSED	REAR END FIRE SCENARIOS ADDRESSED	NON-COLLISION FIRES	CRASHWORTHINESS: ACTIVATED BY CRASH	RATED FOR HIGH G-LOADS	NO ELECTRICITY NEEDED	FLEXIBLE	DAMAGED CAN STILL FUNCTION	MULTIPLE ACTIVATION MEANS	ACTIVATED BY HEAT, FIRE	TOTAL	STAGE OF DEVELOPMENT	WEIGHT: ACTUAL WEIGHT	WEIGHT POINTS	TOTAL
FIRE RESISTANT FABRICS 5		F														0	0
FIRE RESISTANT FABRICS 5		R														0	0
FIRE RESISTANT FABRICS 5		F/R														0	0
INTUMESCENT/ABLATIVE COATING 1		F	3 a,b,c (7.5)		5		x	x	x	x	x	x	24	10	6	6	52.5
INTUMESCENT/ABLATIVE COATING 1		R		3 (2.5)	5		x	x	x	x	x	x	24	10	30	0	41.5
INTUMESCENT/ABLATIVE COATING 1		F/R	3 a,b,c (7.5)	3 (2.5)	5		x	x	x	x	x	x	24	10	36	0	49
INTUMESCENT/ABLATIVE COATING 2		F	3 a,b,c (7.5)		5		x	x		x	x	x	20	12.5	7	6	51
INTUMESCENT/ABLATIVE COATING 2		R		3 (2.5)	5		x	x		x	x	x	20	12.5	35	0	40
INTUMESCENT/ABLATIVE COATING 2		F/R	3 a,b,c (7.5)	3 (2.5)	5		x	x		x	x	x	20	12.5	42	0	47.5
INTUMESCENT/ABLATIVE COATING 3		F	3 a,b,c (7.5)		5		x	x		x	x	x	20	10	7.5	6	48.5
INTUMESCENT/ABLATIVE COATING 3		R		3 (2.5)	5		x	x		x	x	x	20	10	37.5	0	37.5
INTUMESCENT/ABLATIVE COATING 3		F/R	3 a,b,c (7.5)	3 (2.5)	5		x	x		x	x	x	20	10	45	0	45

ASSUMPTIONS (APPENDIX D)

TECHNOLOGY PRODUCTS	APPLICATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
FIRE RESISTANT FABRICS 5	F																			X										
FIRE RESISTANT FABRICS 5	R																			X										
FIRE RESISTANT FABRICS 5	F/R																			X										
INTUMESCENT/ABLATIVE COATING 1	F						X									X	X													
INTUMESCENT/ABLATIVE COATING 1	R						X									X	X													
INTUMESCENT/ABLATIVE COATING 1	F/R						X									X	X													
INTUMESCENT/ABLATIVE COATING 2	F						X									X	X													
INTUMESCENT/ABLATIVE COATING 2	R						X									X	X													
INTUMESCENT/ABLATIVE COATING 2	F/R						X									X	X													
INTUMESCENT/ABLATIVE COATING 3	F						X									X	X													
INTUMESCENT/ABLATIVE COATING 3	R						X									X	X													
INTUMESCENT/ABLATIVE COATING 3	F/R						X									X	X													

APPENDIX F: SURVEY RESPONDER POINTS OF CONTACT

AERO TEC LABORATORIES INC. Speer Road Industrial Park Ramsey NJ 07446- 125 1 (crash resistant fuel tank)	BERK-TEK 132 White Oak Road New Holland PA 17557 (fire resistant plastics)
AFEX 5808 Lease Drive Raleigh NC 276 13 (conventional fire extinguishers)	BF GOODRICH SPECIALTY CHEMICAL 99 11 Brecksville Rd. Cleveland OH 44 14 l-3247 (fire resistant plastics)
AMEREX CORPORATION 7595 Gadsden Highway P.O. Box 81 Trussville AL 35 173-008 1 (conventional fire extinguishers, fire detectors, gas detectors)	BLOCKSOM & CO. Filtration Products Division 5th and Canal Streets P.O. Box 477 Michigan City IN 46360 (fire resistant filter)
AMFUEL P.O. Box 887 Magnolia AR 71753 (crash resistant fuel tanks)	BNZ MATERIALS, INC. BNZ House 6901 South Pierce St., Ste. 260 Littlejohn CO 80123 (fire resistant fabrics)
ANSUL FIRE PROTECTION 1 Stanton St. Marinette WI 54143 (conventional fire extinguisher, aerosol generators, spot detectors)	THE CELOTEX CORPORATION 4010 Boy Scout Boulevard Tampa FL 33607 (fire resistant plastics)
CREST FOAM INDUSTRIES, INC. 100 Carol Place Moonachie NJ 07074 (reticulated foam)	ELF ATOCHEM NORTH AMERICA INC. 900 First Avenue P.O. Box 1536 King of Prussia PA 19406-0018 (fire resistant plastics)
DONMAR LTD. 901 Dover Drive, Suite 120 Newport Beach CA 92660 (machine vision detector)	ENGINEERED FABRICS CORP. 669 Goodyear St. Rockmart GA 30153 (self-sealing materials/fuel tanks/reticulated foam)
DOW CORNING CORPORATION Midland MI 48686-0994 (intumescent/ablative coatings)	FIREBOY-XINTEX 100 Commerce Avenue S.W. Grand Rapids MI 49503 (conventional fire extinguishers, detectors, engine shut off devices)

DUPONT AUTOMOTIVE 950 Stephenson Highway Troy MI 48007-70 13 (fire resistant fabrics)	FIRE COMBAT, INC. 2650 Industrial Parkway P.O. Box 407 Marinette WI 54 143-0407 (aerosol generators)
DYN-OPTICS 22971 Triton Way, Unit B Laguna Hills CA 92653 (fire detectors)	FIREMASTER EXTINGUISHER LTD. Firex House 174- 176 Hither Green Lane London SE13 GQB England (conventional fire extinguishers, linear detectors)
FIREXX CORPORATION 1611 N. Kent St., Ste. 1000 Arlington VA 22209 (flame arrestor material)	METALCRAFT INC. 933 1A Philadelphia Rd. Baltimore MD 21237 (conventional fire extinguishers, engine shutdown systems)
FLAG FIRE INC. 5655 Opportunity Drive Toledo OH 436 12 (conventional fire extinguisher)	MORTON AUTOMOTIVE SAFETY PRODUCTS 3350 Airport Rd. Ogden UT 84405 (gas generators, conventional fire extinguishers, fuel shutoff devices)
GENERAL MONITORS 26776 Simpatica Circle Lake Forest CA 92630 (fire detectors)	NOFIRE TECHNOLOGIES, INC. 21 Industrial Ave. Upper Saddle River NJ 074582301 (intumescent/ablative coatings)
HICKORY SPRINGS MFG. CO. P.O. Box 128 Hickory NC 28603-0128 (fire resistant fabrics)	OLIN AEROSPACE CO 11441 Willows Road N.E. P.O. Box 97009 Redmond WA 98073-9709 (gas generators)
ICI EXPLOSIVES Nobel's Explosives Company Limited Building AK1 Ardeer Site Stevenston Ayrshire England KA20 3LN (fluid shutoff devices)	PPG INDUSTRIES, INC. Research and Development Center 151 Colfax St. Springdale PA 15144 (intumescent/ablative coatings)
KIRCHNER FIRE EXTINGUISHER INC. 4420 W. Hi Point Road McHenry IL 60050 (conventional fire extinguishers)	POWSUS INC. 1178 Wisteria Drive Malvem PA 19355 (tubular extinguishing system)

RELIABLE AUTOMATIC SPRINKLER CO. 525 North MacQuesten Parkway Mt. Vernon NY 10552-2600 (conventional fire extinguishers)	SPECIALTY PAPERBOARD Latex Fiber Products Division Beaver Falls NY 13305 (fire resistant fabrics)
REYNOLDS INDUSTRIES, INC. 5005 McConnell Ave. Los Angeles CA 90066-6734 (fuel shutoff devices)	SPECTREX, INC Peckman Industrial Park 2 18 Little Falls Road Cedar Grover NJ 07009 (aerosol generators, conventional fire extinguishers, fire detectors)
SANTA BARBARA DUAL SPECTRUM 163 Aero Camino Goleta CA 93 117 (conventional fire extinguishers, explosion suppression systems, linear detectors)	WOOD GROUP FIRE SYSTEMS Fire Systems House 19 Colthrop Way Thatcham Berkshire England RG19 4LN (conventional fire extinguishers, linear detectors)